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UNIVERSITY OF MICHIGAN
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VOLUME 19 MARCH, 1945 NUMBER 2

A CONTRIBUTION TO OSTRACODAL ONTOGENY

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ABSTRACT.—Certain ostracode species pass through a series of ontogenetic molt stages, each of which is characterized by valves differing in structural detail. Inadequate knowledge of this ontogenetic sequence may lead to erroneous biologic classification and incorrect stratigraphic and geographic recordings of a species. *Cythereis simiensis* (LeRoy) from the Pliocene of southern California and *Cythereis holmani* LeRoy from the Miocene of central Sumatra, Netherlands East Indies, have been selected to illustrate the various stages through which a species may be expected to pass before attaining maturity.

FOR a number of years micropaleontologists have suspected that certain species of ostracodes pass through a series of molt stages before attaining maturity, but very little systematic investigation of this problem has been reported. Kellett (1943) recognized a large percentage of immature molts in Paleozoic and Cretaceous ostracode collections. Regarding some Permian forms she stated,

> Permian representatives of the Kirkbyidae and Kloedenillidae evidently molted especially often, some individuals, perhaps as many as six times.

The present study has given substantial evidence that certain species of ostracodes periodically shed their calcareous valves, and at the termination of each growth stage new valves were secreted which were larger and structurally more advanced than their predecessors. Each of these shedding periods constitutes a molt stage. The number of molt stages for various species and genera may differ, depending on their developmental cycles. Additional researches are required to determine whether or not all ostracodal forms have a specific molt history.

During the writer's investigation of the Pleistocene and Pliocene marine and freshwater ostracode faunas of the coastal region of southern California and of the Miocene faunas of central Sumatra, Netherlands East Indies, the molt sequences of several species were recognized. Without careful analysis and evaluation of these sequences, identification of early molts was difficult because of the dissimilarity of early and late moults. The structural differences between early and late molts are considerable and are reflected in size and shape of the valve, hinge structure, ornamentation, muscle scar pattern, marginal areas and pore canal systems.

A survey of the literature shows that most investigators of the Ostracoda (including the writer) have failed to recognize or emphasize the significance of molt variants. As a result of this neglect, frequent generic and specific allocations have been made erroneously. To minimize faulty ostracodal correlations and to reduce taxonomic confusion as much as possible, the evaluation

of early molt valves in terms of final molt valves should be made when the micropaleontologist compiles the range and distribution of a species.

The genera *Cythereis* Jones and *Archicythereis* Howe are involved in this study. There has been considerable controversy regarding the validity of the latter genus. In the original description Howe indicated that he was fully aware that certain species assigned to that genus might represent young molts of other genera. The present investigation has shown that a number of forms that seem to meet the requirements of *Archicythereis* are early molt stages of *Cythereis*. Thus from a practical viewpoint, *Archicythereis* is a useless genus and it is recommended that its use be discontinued until and unless it is satisfactorily redefined.

The name *Archicythereis* is used occasionally in this paper. This usage, however, refers only to the particular hinge structure and marginal pore canal system exhibited by the early molts of the two species discussed and is not intended to signify generic allocation.

To demonstrate molt progress, *Cythereis simiensis* (LeRoy), originally described from the San Diego formation ("Middle Pliocene") of southern California and *Cythereis holmani* LeRoy from the Miocene of central Sumatra, were selected. The valves of each respective molt stage of these two species exhibit sufficient overlapping structural affinities to the valves of preceding and subsequent stages to establish ontogenetic relationships. In order to minimize the probability of error in the determination of these interrelationships, valves of the entire sequence of each species were obtained from the same locality and assemblage. Nevertheless, the molt stages herein defined are inferences, as the species dealt with are fossil forms and their metamorphosis cannot be actually observed.

I wish to express my appreciation to Mr G. C. Gester and the late Dr. J. O. Nomland of the Standard Oil Company of California for permission to publish the results of this study and to Mr. W. H. Holman of the Standard Oil Company of California for material containing the *Cythereis simiensis* sequence. I am deeply indebted to Mr. A. Hamid of the Nederlandsche Pacific Petroleum Maatschappij, Medan, Sumatra for his interest in this problem and his careful drawings of the specimens. Dr. H. G. Schenck of Stanford University, Mrs. H. J. Plummer of the University of Texas, and Mr. M. B. Stephenson of the Stanolind Oil and Gas Company have kindly criticised my manuscript. I am greatly indebted to Mr. Chalmer L. Cooper of the Illinois Geological Survey for bringing to my attention the first and second molt stages of *Cythereis simiensis* which were overlooked in the original study of the species.

Unfortunately most of the original specimens upon which this study was based, were lost during the Japanese invasion of the Netherlands East Indies. However, valves representing the molt stages of *Cythereis simiensis* have been deposited for reference in the paleontological collections of Stanford University, Palo Alto, California, and the Colorado School of Mines, Golden, Colorado. Valves representing the molt stages of *Cythereis holmani* can not be duplicated at present.

Family CYTHEREIDAE Baird
Genus CYTHEREIS Jones
CYTHEREIS SIMIENSIS (LeRoy)
Plate 9, figures 1–13

Pyricythereis simiensis LeRoy, 1943, Jour. Paleontology, vol. 17, no. 4, p. 368, pl. 61, figs. 24–28.
Archicythereis holmani LeRoy, 1943, Jour. Paleontology, vol. 17, no. 4, p. 371, pl. 58, figs. 1–4; pl. 62, figs. 23, 24.
Archicythereis newportensis LeRoy, 1943, Jour. Paleontology, vol. 17, no. 4, p. 372, pl. 58, figs. 5–8.

Detailed study has revealed that this species is represented by valves of at least seven distinct molt stages. Statistical analysis of the assemblage[1] shows that the right valves of these moult stages occur in the following ratio (beginning with the earliest): 1:1:19:34:32:1:24. The second, third, fourth, and fifth moults clearly exhibit the hinge structure, marginal area, and pore canal system typical of *Archicythereis* Howe. The sixth molt is of special interest because it combines characters of the fifth and seventh

[1] Locality L-9. Newport Lagoon. Scaled 2.95 inches north and 1.08 inches east from the southwest corner of Tustin Quadrangle, U. S. Geol. Survey, Orange County, Calif.

molts. Valves of the seventh, or final molt, exhibit decided affinities to the genus *Cythereis* Jones.

To systematically follow the ontogenitical development of *Cythereis simiensis* (LeRoy), each molt stage beginning with the earliest known is discussed.

FORM A'' (First molt stage, not illustrated). One left valve of this earliest molt stage was observed. Valve very thin, transparent, exhibits only faint indication of surface ornamentation like second and third molts; length 0.35 mm., height 0.19 mm.; hinge structure not clearly discernible; muscle scar node faintly developed; denticulations not observed.

FORM A' (Second molt stage, not illustrated). Two left and two right valves represent this stage. Valves slightly more advanced in structure and ornamentation than first molt; length 0.45 mm.; height 0.27 mm.; valves thin, fragile; hinge structure of *Archicythereis* type; few denticulations present on anterior extremity; muscle scar node moderately developed; surface characteristics approach those of third molt but not as well exhibited.

FORM A (Third molt stage, pl. 9, figs. 1, 2). Valves small, thin, transparent; average length of right valve 0.54 mm., height 0.31 mm.; dorsal and ventral margins straight, diverge anteriorly toward broadly rounded, slightly oblique faintly denticulate extremity rimmed with sharp, thin, transparent ridge extending along entire ventral margin; posterior extremity bluntly pointed with few small denticulations; surface smooth except for occasional, narrow, faint ridges radiating toward anterior margin from rather conspicuous, moderately elevated, rounded muscle scar node located medianly and just anterior to middle; sharp, transparent ventro- and dorsolateral expansion present with former more strongly developed and attaining greatest elevation posteriorly; hinge structure delicate; right valve with two low, compressed, smooth, straight to slightly curved teeth connected by narrow,

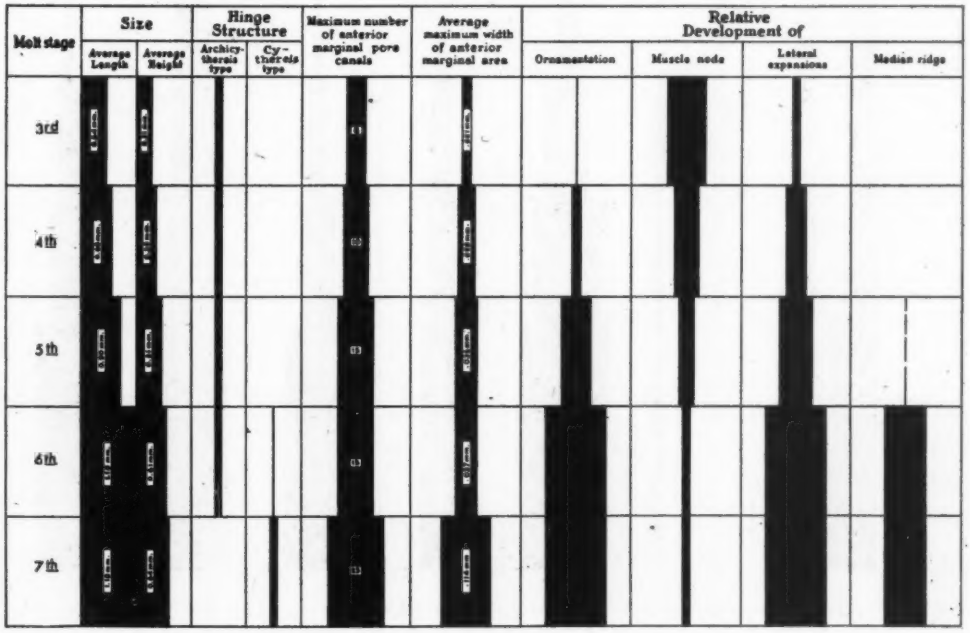


FIG. 1—Chart showing development of third to seventh molt stages of *Cythereis simiensis* (LeRoy). Width of lines relative where numerical values are not indicated.

finely crenulated marginal groove; left valve with two elongate dental sockets connected by narrow, finely crenulated ege corresponding to groove of right valve; anterior and posterior marginal areas exceptionally narrow, with few straight, widely but uniformly heavy; surface pattern, denticulations and scalloped effect around anterior rim assume proportions easily recognized in subsequent molt; several small ovate to elliptical shaped muscle spots occasionally observed within or circumscribing circular median depression;

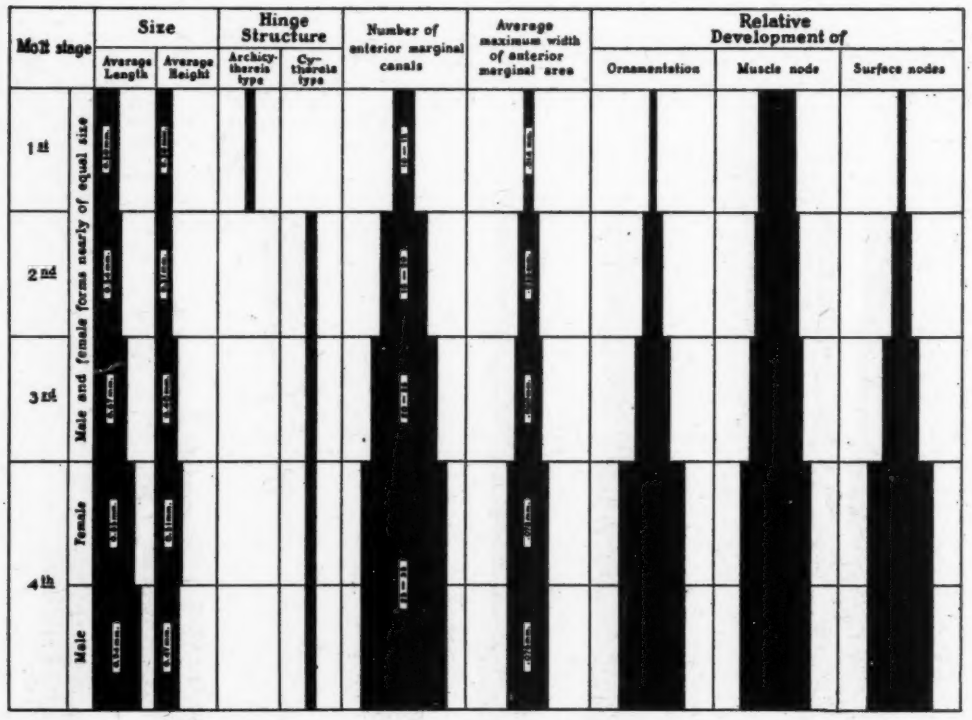


FIG. 2—Chart showing development of molt stages of *Cythereis holmani* LeRoy. Width of lines relative where numerical values are not indicated.

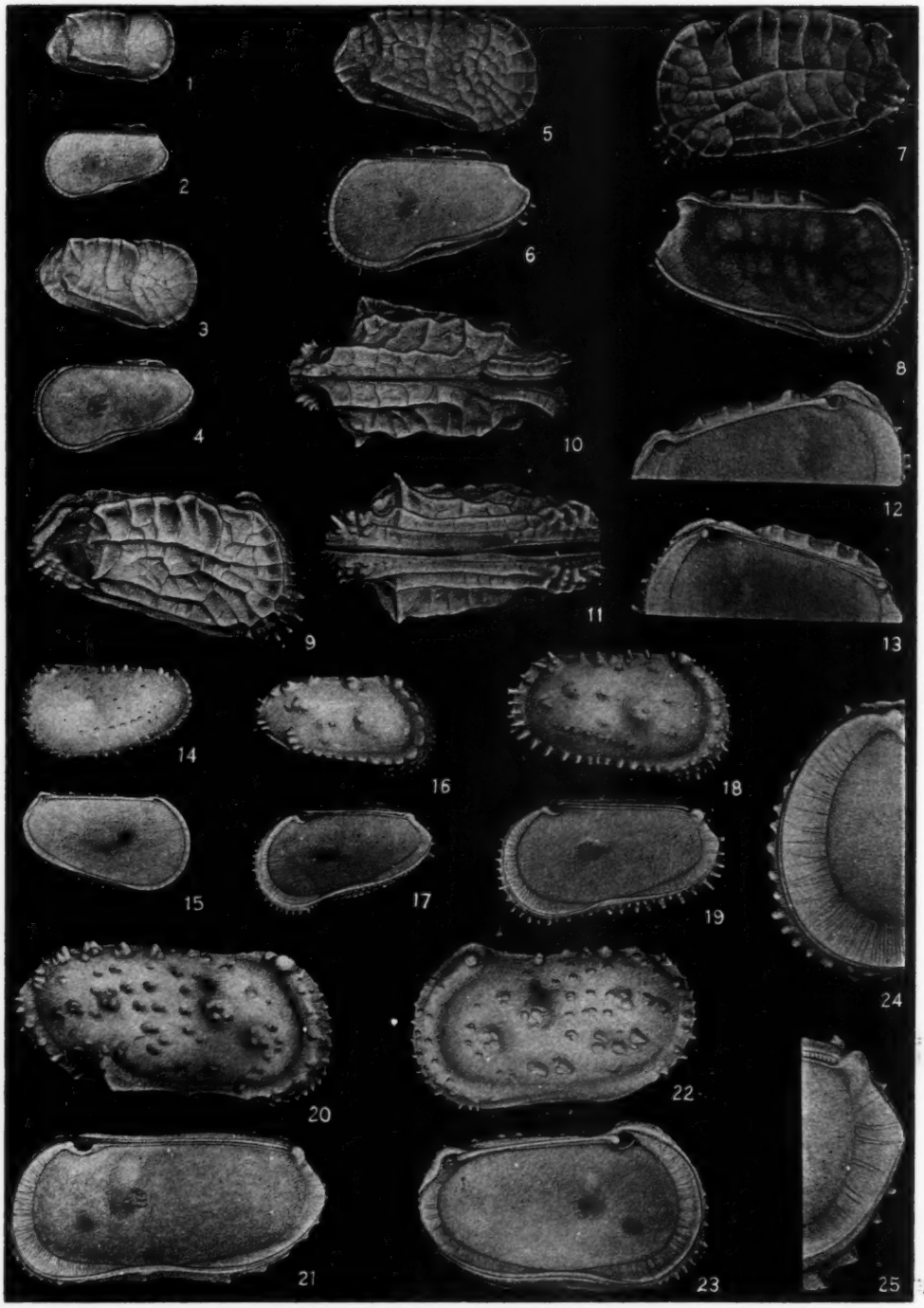
spaced pore canals two or three of which are present on posterior and 6 to 8 on anterior; muscle scar a circular depression without visible attachment spots.

IDEOTYPE. Colorado School of Mines Collection no. 1.

FORM B (Fourth molt stage, pl. 9, figs. 3, 4). This molt is represented by the form originally assigned to *Archicythereis newportensis* LeRoy. Carapace somewhat heavier than first molt; right valve average length 0.68 mm., height 0.39 mm.; outline, hinge structure, surface ornamentation similar to first molt, though more strongly developed; ventro- and dorsolateral ridges moderately anterior marginal pore canals straight, widely spaced, usually number 8 to 10, 4 or 5 on posterior.

IDEOTYPE. Colorado School of Mines collection no. 2.

FORM C (Fifth molt stage, pl. 9, figs. 5, 6). This molt is represented by the form originally assigned to *Archicythereis holmani* LeRoy. Carapace moderately heavy, average length 0.90 mm., height 0.51 mm.; general outline nearly identical to third and fourth molts; hinge structure, surface ornamentation, muscle scar, marginal areas similar to fourth molt, though better developed; pore canals straight, uniformly and widely



LeRoy—Ostracodal Ontogeny

spaced, 12 to 15 on anterior, 6 to 8 on posterior; surface pattern, denticulations, lateral expansions conspicuously developed; posterior half of some valves exhibits small median ridge which becomes stronger in sixth and seventh molts; distinct scalloped ridge around inside of anterior marginal rim; muscle scar pattern similar to fourth molt.

IDEOTYPE. Colorado School of Mines Collection no. 3.

FORM D (Sixth molt stage, pl. 9, figs. 7, 8). The valves of this molt are transitional between *Archicythereis* and *Cythereis* and represent the most critical developmental stage in the molt sequence of the species. Size, outline, denticulations, surface ornamentation, closely similar to seventh or final molt; marginal area, pore canals definitely resembling fifth molt; hinge structure intermediate in development between fifth and seventh molts, left valve with very small, high rounded smooth anterior tooth that becomes prominent in final molt. Valves of this form exceptionally rare.

IDEOTYPE. Colorado School of Mines Collection no. 4.

FORM E (Seventh molt stage, pl. 9, figs. 9–13). This is the mature stage of *Cythereis simiensis* (LeRoy) as originally described. Valves exceptionally heavy, robust; hinge structure, surface ornamentation, median ridge, denticulations, marginal areas strongly developed; average length 1.18 mm.; height 0.64 mm.; hinge structure not of *Archicythereis* type as in sixth molt but with characters of *Cythereis;* hinge of right valve (pl. 9, fig. 13) with smooth, rounded, anterior tooth, deep postjacent socket, straight narrow, finely crenulated marginal groove and high, smooth, rounded posterior tooth; hinge of left valve with deep anterior socket, small low, postjacent tooth connected with narrow, straight, finely crenulated edge extending to rounded posterior socket; marginal areas wide; anterior marginal pore canals numerous, (maximum, 25) irregularly spaced, frequently tending to intersect and group; muscle scar area depressed, sometimes containing several ovate spots.

IDEOTYPE. Colorado School of Mines Collection no. 5.

CYTHEREIS HOLMANI LEROY

Plate 9, figures 14–25

Cythereis holmani LeRoy, 1939, Natuurk tijdschr. Ned.-Indie, afl. 6, vol. 99, p. 276, pl. 10, figs. 1–8.

The mature form of this species was originally described from the Miocene of the east coastal area of central Sumatra where it occurs in appreciable numbers in the shallow marine facies of the Telisa formation. It is found associated with the foraminifers *Cibicides dorsopustulosus* LeRoy, *C. tapanoeliensis* LeRoy, *C. koeboeensis* LeRoy, *Textularia malaccaensis* LeRoy and *Elphidium koeboeense* LeRoy.

Specimens closely related to this species have been noted from shallow water marine environments at various localities in the Malay Archipelago and from several Pleistocene and Pliocene localities of west Java. The specimen sequence herein discussed

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EXPLANATION OF PLATE

(Figs. 1–3 ×34; figs. 14–25 ×52; figs. 24, 25 ×90)

FIGS. *1–13—Cythereis simiensis* (LeRoy). *1, 2,* Third molt, Form A, exterior and interior views of right valve. *3, 4,* Fourth molt, Form B, exterior and inteior views of right valves. *5, 6,* Fifth molt, Form C, exterior and interior views of right valve. *7, 8,* Sixth molt, Form D, exterior and interior views of left valve; this molt possesses surface characters of seventh molt and marginal area characters of fifth molt. *9–11,* Seventh molt, Form *E, 9,* exterior view of right valve, *10,* dorsal view, *11,* ventral view. *12, 13,* Hinge structures of left and right valves of seventh molt. (p. 82)

14–25—Cythereis holmani LeRoy. *14, 15,* First molt, Form A, exterior and interior views of left valve. *16, 17,* Second molt, Form B, exterior and interior views of right valve. *18, 19,* Third molt, Form C, exterior and interior view of right valves. *20–23,* Fourth molt, Form D. *20, 21,* Exterior and interior views of right valve of male. *22, 23,* Exterior and interior views of left valve of female., *24, 25* ×120. Details of anterior and posterior marginal areas of right valve, Form D. Note irregular spacing, grouping and intersection of marginal pore canals. (p. 85)

was selected from a single locality.[2] At least four molt stages of the species have been recognized and their relationships graphically shown in text figure 2.

FORM A (First molt stage, pl. 9, figs. 14, 15). This form is the earliest known molt stage of the species. Valves very thin, transparent, with delicate *Archicythereis*-type hinge structure; average length 0.50 mm., height 0.30 mm.; surface smooth except for series of small, widely spaced, sharp spines along posterior half of dorsal margin, around lower posterior, ventral and anterior margins; rather strongly developed muscle scar node on median line just anterior to middle; anterior and posterior inner marginal areas exceptionally narrow, with 10 to 12, straight, widely, uniformly spaced pore canals; muscle scar area deep, circular, depressed.

FORM B (Second molt stage, pl. 9, figs. 16, 17). Possibly an intermediate molt stage exists between this form and the stage described above though no specimens were observed in the assemblage. Valves moderately heavy, with *Cythereis* hinge structure; average length 0.54 mm.; height 0.31 mm.; marginal areas, pore canals similar to subsequent molts; surface ornamentation more strongly developed than in first molt; anterior and ventral spines of first molt merged to give scalloped effect but many specimens fail to exhibit this feature as distinctly as the one figured; marginal areas wide, with numerous closely spaced, frequently intersecting pore canals; posterior and anterior denticulations and muscle scar node more pronounced than in preceding molt; muscle scar area similar to Form A.

FORM C (Third molt stage, pl. 9, figs. 18, 19). Valves representing this molt exhibit the maximum development of peripheral spines and distinctly scalloped ridge around anterior margin. Average length 0.67 mm.; height 0.40 mm.; dorsal and ventral margins more nearly parallel than in either of preceding stages; general structure, character of marginal areas, pore canals similar to subsequent molt.

FORM D (Fourth molt stage, pl. 9, figs. 20–22). *Cythereis holmani* LeRoy as originally described is the final stage in this molt sequence. Male (pl. 9, figs. 20, 21) and female (figs. 22, 23) forms may be easily distinguished by differences in size and degree of inflation of the posterior half. Average length (female) 0.85 mm.; height 0.51 mm.; average length (male) 0.94 mm.; height 0.47 mm.; surface nodes relatively low, quite rounded, more numerous than on preceding molts; anterior marginal rim heavy, smoothly rounded, with few, widely spaced superimposed nodes; scalloped effect of Form C not conspicuous; ventral spines so well developed on Form C not present because of wear or breakage; this margin in some specimens seminodose; cardinal tubercle, first conspicuous in third molt, quite well developed; anterior and posterior inner marginal areas wide, with numerous intersecting or grouped pore canals (pl. 9, figs. 24, 25); two rather conspicuous external surface nodes present, one corresponding to muscle node of preceding molts, other located just below it anteriorly, both indicated on inside by circular or elliptical depressions; primary muscle scar depression generally with three or four small elongate-ovate muscle attachment spots on posterior border.

[2] N-5500. Depth 6 meters. Eleven kilometers S.20°W. from Kampong Doemai. Sultanate of Siak; East Coast of Sumatra, Netherlands Government Topographic Blad 20/xiv.

MANUSCRIPT RECEIVED SEPTEMBER 8, 1943.

REFERENCES

HOWE, H. V., and LAW, J., 1936, Louisiana Vicksburg Oligocene Ostracoda: Louisiana Dept. Cons. Bull. 7.

KELLETT, B., 1943, Permian Ostracodes: Journ. Paleontology, vol. 17, no. 6, pp. 615–628.

LEROY, L. W., 1943, Pleistocene and Pliocene Ostracoda of the Coastal Region of Southern California: Journ. Paleontology, vol. 17, no. 4, pp. 354–373.

STEPHENSON, M. B., 1936, Shell structure of the ostracode genus *Cytheridea:* Journ. Paleontology, vol. 10, pp. 695–703.

——, 1937, Middle Tertiary Ostracoda of the genus *Cytheridea* from Florida: Journ. Paleontology, vol. 11, no. 2, pp. 145–159.

——, 1941, Notes on the subgenera of the Ostracode genus, *Cytheridea:* Journ. Paleontology, vol. 15, no. 4, pp. 424–429.

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OSTRACODA OF THE PLUM BROOK SHALE, ERIE COUNTY, OHIO

GRACE ANNE STEWART
Ohio State University
AND
WILLIAM EDWIN HENDRIX
On Active Service with the U. S. Army

ABSTRACT.—Ostracodes recovered from samples of the Plum Brook shale collected during the Autumn of 1939 have formed the basis for this study. Three new genera, 7 new species, and one new variety have been recognized. The new genera are: *Punctoprimitia*, *Bythocyproidea*, and *Eriella*. A list of locations showing the occurrence of the species is included.

ROCKS of Hamilton age in Erie County, northern Ohio, are represented by the Prout limestone and the underlying Plum Brook shale. Stratigraphically these formations occupy the interval between the Huron shale above and the Delaware limestone below. On both a stratigraphic and faunal basis Cooper (1933, p. 123) has suggested the correlation of the Prout limestone with the Centerfield of New York, and the Plum Brook shale with the Levanna (upper Skaneateles). Stumm (1942) shows further evidence to support this correlation, and in addition divides both formations into zones. The age equivalence of these two formations with the New York formations appears probable.

At various times and by different authors both the Prout limestone and Plum Brook shale have been correlated with the Olentangy shale of central Ohio, exposed along the Olentangy River in Franklin and Delaware counties. Others, however, have opposed this viewpoint. Both sides of the question have been ably summed up in Stumm's paper. On the basis of their study of the ostracodes in the Plum Brook shale and the Olentangy shale the present writers cannot accept the equivalence of these two formations. The ostracodes bear little resemblance to one another, and appear to represent two separate and distinct faunas. Other faunal dissimilarities of the Prout limestone and Olentangy shale have likewise been reported.

The Prout limestone is a hard, siliceous, generally grey to brown limestone, varying in thickness from 3 to 9 feet. It is quite fossiliferous, yielding mostly poorly preserved corals and brachiopods. The underlying Plum Brook shale is a soft grey shale, with interbedded bands of argillaceous limestone. On the outcrop seldom more than 20 feet of it are exposed, although under cover it is said to attain a thickness of 60 feet in places. It is generally abundantly fossiliferous carrying a fauna very similar to the upper Silica shale.

So far the megascopic fossils in the Plum Brook shale have received most notice, and little attention has been given the microscopic forms. The group of microfossils that have been studied most carefully are the conodonts which were described by Stauffer (1938). The only recognition that has been given the ostracodes was by Stauffer (1916, p. 476) who listed six species: *Bairdia devonica* (Ulrich), *Barychilina* sp., *Bollia* sp., *Bythocypris indianensis* (Ulrich), *B. punctatus*, and *Ponderodictya punctulifera* (Hall). The present study was undertaken with the hope that additional evidence on the ostracodes might be revealed.

Twenty-two samples of shale were collected from several outcrops and carefully broken down and examined. Ten of them were found to contain ostracodes. Altogether 19 species have been identified. In addition 5 other species have been recognized but their identification is so uncertain because of poor preservation that they have not been included in this report. Although these 19 additional species do not constitute a prolific group they do give a more complete picture of the ostracode element in the total fauna than was known before.

The Hamilton age of the ostracodes is readily recognized by such species as *Ponderodictya unicornis*, *Ulrichia conradi*, *Octonaria crescentiformis*, *Poloniella cingulata*, and *Kirkbyella bellipuncta transversa*. Likewise their resemblance to the Silica shale ostracodes in northwest Ohio is striking. Seven species are common to both formations and undoubtedly there are others that have not yet been recognized. The species represented in both formations are: *Ulrichia conradi* (Jones), *Punctoprimitia simplex* (Stewart), *Dizygopleura trisinuata* Van Pelt = *D. oblonga* Warthin of the Silica shale, *Poloniella cingulata* Warthin, *Ponderodictya ohioensis* (Stewart), *P. unicornis* (Van Pelt) = *P. punctulifera* (Hall) of the Silica shale.

Of the 6 species reported by Stauffer we have recognized with certainty only one, *Ponderodictya punctulifera* (Hall) = *P. unicornis* (Van Pelt). *Bollia* sp., may be the same as our *Hollina* sp., and the two species of *Bythocypris* may correspond to our *Bythocyproidea eriensis* and *B. sanduskyensis* respectively.

In no sample examined have specimens been anywhere nearly so abundant as in some zones of the Silica shale. Sample 3g yielded 9 species, the greatest number recovered from any of the samples. No species is represented by numerous individuals, the most abundant and widely distributed being *Quasillites? pseudobrevispinata*, which has been found in all samples except 3d and 3e. In samples 2b, 3a, and 3b this is the only form recognized. Shell material and details of surface sculpture are well preserved in most specimens.

The following species have been recognized and are described in this paper:

Aparchites anonyma Stewart and Hendrix, n. sp.
Aechmina crenulata Stewart
Ulrichia conradi Jones
Hollina sp.
Punctoprimitia simplex (Stewart) n. gen.
Dizygopleura euglyphea Warthin
Dizygopleura trisinuata Van Pelt
Kirkbyella bellipuncta transversa n. var.
Octonaria crescentiformis Van Pelt
Poloniella cingulata Warthin
Bythocyproidea eriensis Stewart and Hendrix, n. gen., n. sp.
Bythocyrpoidea sanduskyensis Stewart and Hendrix, n. sp.
Lucasella cavanifera Stewart and Hendrix, n. sp.
Lucasella dubia Stewart and Hendrix, n. sp.
Ponderodictya ohioensis (Stewart)
Ponderodictya unicornis (Van Pelt)
Quasillites obliquus Coryell and Malkin
Quasillites? pseudobrevispinata Stewart and Hendrix, n. sp.
Eriella robusta Stewart and Hendrix, n. gen., n. sp.

LOCALITIES AND OCCURRENCE OF SPECIES

1. Stahl farm. The abandoned quarry on this farm, the former Allen Farr farm on the Bellevue road, three-fourths of a mile from the Huron-Erie county line in Erie county; Bellevue Quadrangle, T 5 N, R 24 W, SW¼ SE¼ (1) of the township.

1a—From fossiliferous bluish shale and a compact 4-inch nodular fossiliferous bluish limestone above; extends from 12 feet 5 inches to 15 feet 5 inches below the top of the formation; 50 yards west of the old quarry; *Dizygopleura euglyphea, D. trisinuata, Octonaria crescentiformis, Ponderodictya ohioensis, P. unicornis, Quasillites obliquus, Q.? pseudobrevispinata.*

2. Pipe Creek, Bloomingville. The north branch of Pipe Creek, southeast of Sand Hill and about one-fourth mile west of the village of Bloomingville where the road crosses the creek; Bloomingville: Sandusky Quadrangle, T 5 N, R 23 W, NW¼ NW¼(3) of the township.

2a—From a very fossiliferous argillaceous bluish limestone layer exposed on the creek bottom; *Dizygopleura euglyphea, D. trisinuata, Octonaria crescentiformis, Ponderodictya ohioensis.*
2b—The lowest layer of soft blue shale exposed in the stream bed, 50 yards north of the road bridge: *Quasillites? pseudobrevispinata.*

3. Plum Brook. About two miles northeast of Prout station on the Baltimore and Ohio Railroad, along the creek; Sandusky Quadrangle, T 6 N, R 23 W, SW¼ SE¼ (1) of the township.

3a—From the lower 15 feet of the formation at a point 10 yards north of the road bridge: *Quasillites? pseudobrevispinata.*
3b—From the lower 15 feet of the formation at a point approximately 240 feet south of the road bridge: *Quasillites? pseudobrevispinata.*
3c—From the lower 15 feet of the formation at a point approximately 260 feet south of the road bridge: *Dizygopleura trisinuata, Quasillites? pseudobrevispinata.*
3d—From the 6-inch layer of fossiliferous soft bluish limestone, and from 0 to 6 inches below in the fossiliferous soft argillaceous bluish shale 6 feet below the contact of the Prout limestone and 14 feet 10 inches below the top of that formation: *Aparchites anonyma, Hollina* sp., *Dizygopleura euglyphea, D. trisinuata, Kirkbyella bellipuncta transversa, Octonaria crescentiformis, Pon-*

derodictya unicornis, Quasillites obliquus.

3e—From a 6-inch layer of quite hard fossiliferous bluish limestone 17 feet below the top of the formation; *Aechmina crenulata, Dizygopleura euglyphea, D. trisinuata, Ortonella robusta.*

3f—The middle 6 inches of a 5 foot fossiliferous soft bluish shale bed 19 feet 4 inches below the top of the formation: *Kirkbyella bellipuncta transversa, Bythocyproidea eriensis, Lucasella dubia, Quasillites obliquus, Q.? pseudobrevispinata.*

3g—From a 5-inch limestone layer and a 4-inch shaly bluish limestone directly below, both fossiliferous, the latter extremely so, 24 feet 6 inches below the top of the formation. This is the most abundantly fossiliferous zone seen in the Plum Creek region: *Ulrichia conradi, Punctoprimitia simplex, Dizygopleura euglyphea, Kirkbyella bellipuncta transversa, Octonaria crescentiformis, Ponderodictya unicornis, Quasillites obliquus, Q.? pseudobrevispinata, Eriella robusta.*

4. Bogart. The bridge excavation now filled by the bridge abutment, about 100 yards east of the center of town where the main street crosses a small tributary of Plum Creek; Sandusky Quadrangle, T 6 N, R 23 W, NE¼ SE¼(1), and SE¼ NE¼(2) of the township.

4a—From the lower 14 inches of a 4-foot section of fresh, soft bluish shale exposed at the bottom of the excavation: *Poloniella cingulata, Bythocypris sanduskyensis, Lucasella cavanifera, L. dubia, Quasillites? pseudobrevispinata, Eriella robusta.*

SYSTEMATIC DESCRIPTIONS

Family LEPERDITELLIDAE Ulrich and Bassler

Genus APARCHITES Jones

APARCHITES ANONYMA Stewart and Hendrix, n. sp.

Plate 10, figure 1

Carapace large; inside view having appearance of truncated ellipse; greatest height and thickness central; hinge line straight, apparently occupying entire dorsal margin, sulcate at midlength; dorsal margin straight, ends acutely angular; ventral margin strongly convex, curving abruptly into ends; posterior margin broadly, evenly rounded; anterior margin most narrowly rounded, most protuberant in dorsal half.

Shell slightly inequivalved, left valve larger, overlapping right at ends and on dorsal margin; hingement unknown. Slight thickening occurs along ends and the ventral margin; valves distinctly bulging in central area, sloping abruptly towards entire margin, surface very finely granulose.

Length measured slightly above mid-height 1.16 mm.; height measured centrally 0.87 mm.; thickness measured centrally 0.58 mm.

A complete cast of the interior constitutes the material at hand. The form resembles *Aparchites? seneca* Hall in general shape, but that species lacks the conspicuous central bulge, and has in addition a slight sulcus.

HOLOTYPE: Ohio State University Geol. Mus. no. 18857, locality 3d.

Family AECHMINIDAE Swartz

Genus AECHMINA Jones and Holl

AECHMINA CRENULATA Stewart

Aechmina serrata Stewart, not Coryell and Cuskley, Jour. Paleontology, vol. 10, no. 8, p. 478, pl. 100, figs. 21, 22, 1936, Silica shale, Dev. Lucas Co., Ohio.

Aechmina crenulata Stewart, idem, vol. 11, no. 4, p. 368, 1937.

This species is represented by one imperfect valve, probably the left one. The specimen is embedded in a rock fragment from which it cannot be separated so that all details are not visible. However, the general aspect is similar and in all probability the specimen belongs in this species.

PLESIOTYPE: Ohio State University Geol. Mus. no. 18884, locality 3e.

Family DREPANELLIDAE Swartz

Genus ULRICHIA Jones

ULRICHIA CONRADI Jones

Plate 10, figure 2

Ulrichia conradi Jones 1890, Geol. Soc. London, Quart. Jour., vol. 46, p. 544, text fig. 2.

Only one small, fragile left valve has been found in the Olentangy shale during the course of this study. It exhibits the typical characters of the species and may be identified with confidence. Two large dorsal nodes, the reticulate surface, and a row of short spines or papillae along the free margin of the valve are distinguishing features.

The writers wholly concur in the opinion of Warthin (1937) and Swartz (1941) in considering *Ulrichia spinifera* Coryell and Malkin (1936) a synonym of this species.

More critical examination of specimens of *Ulrichia conradi* from the Silica shale of northwestern Ohio reveals the well-developed marginal spines, a feature overlooked by the senior author in an earlier study. These specimens are large and much more

robust than those from the Plum Brook shale.

Length 0.66 mm.; height measured in posterior half 0.43 mm.

PLESIOTYPE: Ohio State University Geol. Mus. no. 18886, locality 3g.

Family HOLLINIDAE Swartz
Genus HOLLINA Ulrich and Bassler
HOLLINA sp.
Plate 10, figure 3

One poorly preserved specimen, apparently a right valve, appears to fulfill the requirements of this genus. A portion of the dorsoposterior node is broken away, and the anterior node appears to be obsolete. The middle lobe is rounded and prominent; a smaller secondary lobe occupies the midventral area. A spinose projection anteriorly directed and with the end broken, occurs along the ventroanterior margin. The specimen appears to be a pseudomorph. It resembles somewhat *Hollinella granifera* (Ulrich) but there is no evidence of a marginal frill.

Length 1.45 mm.; height 0.81 mm.

FIGURED SPECIMEN: Ohio State University Geol. Mus. no. 18887, locality 3d.

Family PRIMITIIDAE Ulrich and Bassler
PUNCTOPRIMITIA Stewart and Hendrix, n. gen.

Small, *Primitia*-like shell, with broad posterior border rising into prominent shoulder; elliptical to oval in outline; valves equal, centrally sulcate; surface of shell punctate.

PUNCTOPRIMITIA SIMPLEX (Stewart)
Plate 10, figures 4, 5

Haploprimitia simplex Stewart 1936, Jour. Paleontology, vol. 10, no. 8, p. 743, pl. 100, fig. 5, Silica shale, Lucas Co., Ohio.

Haploprimitia punctata Turner 1939, Bull. Am. Paleontology, vol. 25, no. 88, p. 10, pl. 1, fig. 1, Devonian, Ontario.

Genotype—*Haploprimitia simplex* Stewart.

Two separate valves, a right and a left are at hand. They are undoubtedly specifically identical with those occurring in the Silica shale of Lucas County. In our estimation *Haploprimitia punctata* Turner, from the Devonian of western Ontario is likewise the same.

The abrupt posterior slope, producing a well-defined shoulder, that flattens out marginally into a broad border, leads us to the conclusion that this form should be withdrawn from the genus *Haploprimitia*. These features likewise serve to separate it from the genus *Primitia*.

PLESIOTYPE (2): Ohio State University Geol. Mus. no. 18885, locality 3g.
Also occurs at locality 3f.

Family KLOEDENELLIDAE Ulrich and Bassler
Genus DIZYGOPLEURA Ulrich and Bassler
DIZYGOPLEURA EUGLYPHEA Warthin
Plate 10, figures 6–8

Dizygopleura euglyphea Warthin, 1934, Michigan University, Contrib. Mus. Paleontology, vol. 4, no. 12, p. 210, pl. 1, fig. 7.

This species is represented in our collections by several well-preserved specimens. They are large, robust and entirely characteristic of the species. The interlocking hinge tooth is particularly well developed.

PLESIOTYPE (3): Ohio State University Geol. Mus. no. 18889, locality 1a.

Also occurs at localities 2a, 3d, 3e, and 3g.

DIZYGOPLEURA TRISINUATA Van Pelt
Plate 10, figures 9–11

Dizygopleura trisinuata Van Pelt, 1933, Jour. Paleontology, vol. 7, no. 3, p. 328, pl. 39, figs. 61, 62.

A number of finely preserved specimens in our collections have been identified with this species. The absence of the interlocking hinge tooth as well as the longer and more curving anterior and posteror sulci readily distinguishes this form from the associated *D. euglyphea* Warthin. A number of male dimorphs (*D. oblonga* Warthin) are among the specimens examined. The ends in the male are of almost equal curvature, the anterior shoulder is more acute, and the convexity of the valves is less than in the female.

PLESIOTYPE (3): Ohio State University Geol. Mus. no. 18890, locality 3c.

Also occurs at localities 1a, 2a, 3d, and 3e.

Family KIRKBYIDAE Ulrich and Bassler
Genus KIRKBYELLA Coryell and Booth
KIRKBYELLA BELLIPUNCTA TRANSVERSA Stewart and Hendrix, n. var.
Plate 10, figures 12–14

A few separate valves vary somewhat from the typical form of this species. They are more transverse, the surface sculpture is finer, and the anterior node is less well de-

veloped. They resemble *K. unicornis* Coryell and Malkin from the Hamilton of Ontario in the shape and in having finer reticulations, but differ in their smooth marginal borders. Perhaps these specimens represent a new species, but until additional examples can be obtained the authors prefer to regard them as a variety of the common Hamilton species.

Length of largest specimen, 0.64 mm.; height 0.35 mm.

SYNTYPES (3): Ohio State University Geol. Mus. no. 18892, locality 3g.

Also occurs at localities 3d and 3f.

Family THLIPSURIDAE Ulrich
Genus OCTONARIA Jones
OCTONARIA CRESCENTIFORMIS Van Pelt
Plate 10, figures 15–17

Octonaria crescentiformis Van Pelt, 1933, Jour. Paleontology, vol. 7, no. 3, p. 334, pl. 39, figs. 55–60.

This is a distinctive form that is readily recognized by its reniform shape and the pronounced grooving on the valves. It is less robust than *Octonaria quadricostata* which is the characteristic species of the genus in the Silica shale. All the specimens examined are well preserved and exhibit the essential details of the species in all respects.

PLESIOTYPES: Ohio State University Geol. Mus. no. 18893, locality 1a.

Also occurs at localities 2a, 3d,and 3g.

This species was originally described from the Gravel Point stage of the Traverse formation of Michigan.

Genus POLONIELLA Gurick
POLONIELLA CINGULATA Warthin
Plate 10, figure 18

Poloniella cingulata Warthin 1934, Michigan University, Contrib. Mus. Paleontology, vol. 4, no. 12, p. 212, pl. 1, fig. 9.

Although an abundant form in the Silica shale, one small specimen, evidently a young individual, is the only one which has been observed during the course of this study. Its length is 0.58 mm., as compared with 1.04 mm. for medium-sized specimens from the Silica shale. The union of the anterior and posterior sulci readily distinguishes this form. The posterior hinge tooth is indistinctly shown but is probably present.

Warthin reports this species from the upper Gravel Point stage of the Traverse in Michigan, and states that he did not find it in the higher beds of the Traverse.

PLESIOTYPE: Ohio State University Geol. Mus. no. 18891, locality 4a.

Family BAIRDIIDAE Sars
Genus BYTHOCYPROIDEA Stewart and Hendrix, n. gen.

This genus is similar to *Bythocypris* in general outline, and in having the left valve larger and overlapping the right. It differs in having a well-developed, curving ridge on the postdorsal slope of the right valve in front of which part of the shell is reticulate or coarsely punctate. The ridge is poorly developed on the left valve, but a similar area of coarse punctae is present.

GENOTYPE: *Bythocyproidea sanduskyensis* Stewart and Hendrix, n. sp.

BYTHOCYPROIDEA SANDUSKYENSIS Stewart and Hendrix, n. sp.
Plate 10, figures 26–28

Shell ovoid to semireniform in outline; greatest height slightly posterior to midlength; greatest thickness in middle of posterior half; greatest length midway between dorsal and ventral margins; hinge shallowly sulcate in posterior fourth, otherwise hingement not observed; dorsal margin arcuate; ventral margin slightly convex; ends evenly rounded, posterior end broader.

Shell inequivalved, left valve larger, overlapping right all around, overlap greatest in midventral region; valves moderately, evenly convex.

Postdorsal backward-curving, crescentric shoulder developed on right valve, scarcely visible on left; surface of posterior half of shell rather coarsely punctate, especially in front of shoulder; remainder of surface finely punctate or granulose. Shallow marginal sulcus parallels anterior margins of both valves.

Dimensions of specimen of average size: length measured at midheight 0.63 mm.; height measured postcentrally 0.38 mm.; thickness measured posteriorly 0.29 mm.

The few specimens representing this species are well preserved. The form closely resembles the associated *Bythocyproidea*

eriensis, n. sp., but is smaller, the punctae anterior to the shoulder are coarser, and the shoulder is not surmounted by any visible ridges.

SYNTYPES (3): Ohio State University Geol. Mus. no. 18874, locality 4a.

BYTHOCYPROIDEA ERIENSIS Stewart and Hendrix, n. sp.
Plate 10, figures 23–25

Shell thick, subreniform in outline; greatest length midway between dorsal and ventral margins; greatest height about one third of length from posterior margin; greatest thickness in posterior half; dorsal margin arcuate, sloping more steeply to posterior; hingement not observed; ventral margin straight to slightly convex; posterior margin broadly rounded, most extended in midportion; anterior margin narrowly rounded.

Valves moderately convex, left valve larger, strongly overlapping right all around,

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EXPLANATION OF PLATE 10

All illustrations approximately ×25

FIGS. *1*—*Aparchites anonyma* Stewart and Hendrix, n. sp. Right valve view of cast of interior. Holotype, O.S.U. 18857, locality 3d. (p. 89)

2—*Ulrichia conradi* Jones. Left valve showing large dorsal nodes, reticulate surface, marginal spines. Plesiotype, O.S.U. 18886, locality 3g. (p. 89)

3—*Hollina* sp. View of probable right valve. O.S.U. 18887, locality 3d. (p. 90)

4, 5—*Punctoprimitia simplex* (Stewart). *4*, Right valve; *5*, Smaller left valve. Both show abrupt posterior slope and ridge characteristic of the genus. Plesiotypes, (2), O.S.U. 18885, locality 3g. (p. 90)

6–8—*Dizygopleura euglyphea* Warthin. *6*, Right valve view; *7*, Interior of left valve; *8*, Hinge view showing interlocking hinge tooth characteristic of species. Plesiotypes (3), O.S.U. 18889, locality 1a. (p. 90)

9–11—*Dizygopleura trisinuata* Van Pelt. *9*, Left valve view of female specimen; *10*, Interior female left valve; *11*, Left valve view of male dimorph showing ends of nearly equal curvature. Plesiotypes (3), O.S.U. 18890, locality 3c. (p. 90)

12–14—*Kirkbyella bellipuncta transversa* Stewart and Hendrix, n. var. *12*, *13*, Left and right valves respectively, showing characteristic surface features and transverse character of the species; *14*, Interior right valve. Syntypes (3), O.S.U. 18892, locality 3g. (p. 90)

15–17—*Octonaria crescentiformis* Van Pelt. *15*, Left valve showing typical reniform shape; *16*, Interior right valve; *17*, Dorsal view of another specimen. Plesiotypes (3), O.S.U. 18893, locality 1a. (p. 91)

18—*Poloniella cingulata* Warthin. Right valve view of single specimen found. Plesiotype, O.S.U. 18891, locality 4a. (p. 91)

19, 20—*Lucasella cavanifera* Stewart and Hendrix, n. sp. *19*, Left valve view; *20*, Dorsal view showing sulcus and pronounced convexity of valves. Syntypes (2), O.S.U. 18852, locality 4a. (p. 93)

21, 22—*Lucasella dubia* Stewart and Hendrix, n. sp. Left valve and dorsal views of two specimens. Syntypes (2), O.S.U. 18853, locality 4a. (p. 93)

23–25—*Bythocyproidea eriensis* Stewart and Hendrix, n. g., n. sp. *23*, Right valve showing post dorsal ridge, shoulder and strongly overlapping left valve; *24*, Left valve; *25*, Dorsal view showing convexity of valve and shoulder on right valve. Syntypes (3), O.S.U. 18873, locality 3f. (p. 92)

26–28—*Bythocyproidea sanduskyensis* Stewart and Hendrix, n. sp. *26*, Right valve view showing character of posterior shoulder; *27*, Left valve view; *28*, Dorsal view showing shoulder on right valve. Genotype and paratype (2), O.S.U. 18874, locality 4a. (p. 91)

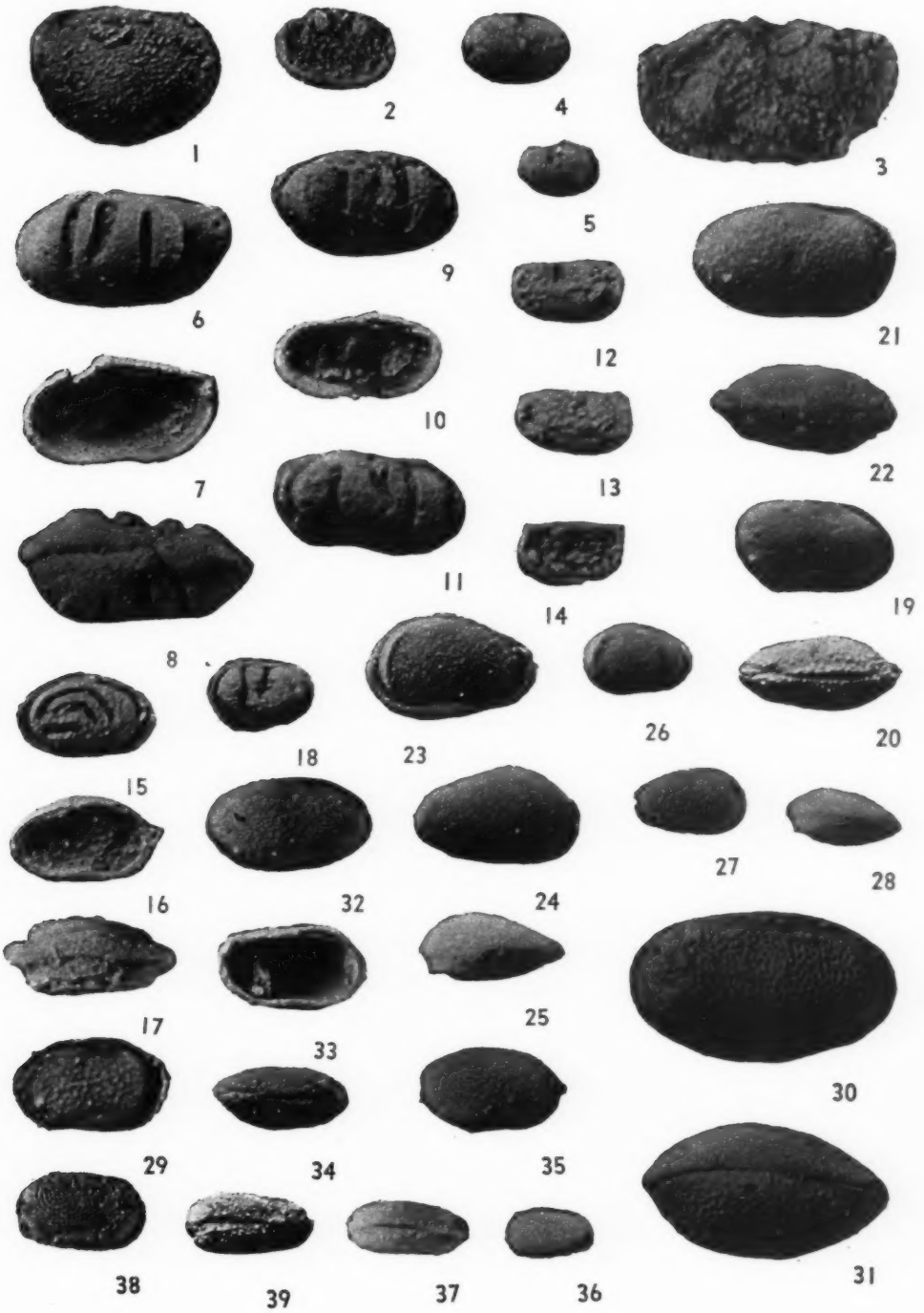
29—*Ponderodictya ohioensis* (Stewart). Right valve of only specimen collected. Syntype, O.S.U. 18896, locality 1a. (p. 93)

30, 31—*Ponderodictya unicornis* (Van Pelt). *30*, Right valve showing characteristic features of the species; *31*, Dorsal view of another specimen. Pleisotypes (2), O.S.U. 18897, locality 3d. (p. 94)

32–34—*Quasillites obliquus* Coryell and Malkin. *32*, Left valve view of specimen showing anteroventral spine; *33*, Right valve interior exhibiting wide contact margin of valves; *34*, View showing sulcus along dorsal margin. Plesiotypes (3), O.S.U. 18899, location 3g. (p. 94)

35–37—*Quasillites pseudobrevispinata* Stewart and Hendrix, n. sp. *35*, Left valve exterior; *36*, Small specimen viewed from right valve; *37*, Dorsal view of another specimen. Syntypes (3), O.S.U. 18872, locality 3b. (p. 94)

38, 39—*Eriella robusta* Stewart and Hendrix, n. g., n. sp. *38*, Left valve view of holotype; *39*, Dorsal view showing somewhat compressed character of valves. Holotype and paratype, O.S.U. 18898, locality 4a. (p. 95)



Stewart and Hendrix—Plum Brook Ostracodes

greatest overlap in middle of ventral, posterior and dorsal margins; margin of shell shallowly sulcate along posterodorsal slope; left valve with conspicuously thickened margins especially along ventral side.

Right valve with posterodorsal shoulder surmounted by weak posteriorly curving concentric ridge; shallow submarginal sulcus parallels anterior margin of each valve; surface finely granulose.

Dimensions of largest specimen: length measured at midheight 0.99 mm.; height measured posteriorly 0.58 mm.; thickness measured posteriorly 0.41 mm.

Three or four well-preserved specimens have been collected. They may be separated from *Bythocyproidea sanduskyensis*, n. sp., by the features mentioned in the discussion of that species.

SYNTYPES (3): Ohio State University Geol. Mus. no. 18873, locality 3f.

Genus LUCASELLA Stewart

LUCASELLA CAVANIFERA Stewart and Hendrix, n. sp.

Plate 10, figures 19, 20

Carapace small, subovate to subrhombic in side view; from right valve view both dorsal and ventral margins appear slightly convex, from left valve view almost straight; postdorsal slope long, gentle, about one third as long as shell; anterior margin more broadly rounded; greatest height and length central, ratio of length to height about 2 to 1; greatest thickness in middle of anterior half; narrow sulcus extends along dorsal margin; detail of hingement not known.

Shell inequivalved, right valve larger, overlapping left along ventral margin and at both ends, ventral overlap greatest. Valves moderately convex, surface finely granulose. Slightly depressed area present in centrodorsal portion of each valve, small rudimentary spine in anterodorsal portion, strongest on left valve. Ventral margin of larger right valve thickened throughout its length, is slightly sulcate at midlength.

Length 0.98 mm.; height 0.75 mm.; thickness 0.46 mm.

Two complete specimens are at hand. This species resembles *Lucasella mundula* of the Silica shale most closely, but differs in the less conspicuous development of the spines, and in having a slight dorsal median depression in each valve.

SYNTYPES (2): Ohio State University Geol. Mus. no. 18852, locality 4a.

LUCASELLA DUBIA Stewart and Hendrix, n. sp.

Plate 10, figures 21, 22

Carapace of medium size, elliptical in outline; dorsal margin moderately convex, merging gradually to ends; ventral margin slightly emarginate at midlength; posterior somewhat more broadly rounded; most extended at midlength; hinge probably extending along entire dorsal margin, sulcate in anterior half.

Shell inequivalved, right valve larger, projecting beyond left on all but anterior half of dorsal margin, over-lapping centroventral margin closely, projecting furthest on posterior end. Inside of valves not observed, hence further details of overlap unknown.

Valves moderately, evenly convex, with slight compression of centrodorsal portion apparent in dorsal view; low ridge formed by slight thickening of shell occurs on anterior half of ventral margin in right valve; low swelling present paralleling posterior margin of left valve; two or three minute, poorly developed nodes present on anterior portion of each valve. Surface finely granulose.

Dimensions of larger specimen: length, measured at midheight, 1.16 mm.; height and thickness respectively, measured anteriorly, 0.63 mm. and 0.55 mm. This species is represented by two well-preserved specimens. It differs in shape and is somewhat larger than *L. cavanifera*.

SYNTYPES (2): Ohio State University Geol. Mus. no. 18853, locality 4a.

Also occurs at locality 3f.

Family CYTHERELLIDAE Sars

Genus PONDERODICTYA Coryell and Malkin

PONDERODICTYA OHIOENSIS (Stewart)

Plate 10, figure 29

Hamiltonella ohioensis Stewart, 1936, Jour. Paleontology, vol. 10, no. 8, p. 757, pl. 101, figs. 22, 23.

Two specimens have been found which appear to have the essential requirements of this species. The nodes, however, are much

less strongly developed, the only conspicuous one being in the postventral region of the right valve. The valves are not quite so convex as is common in specimens from the Silica shale.

PLESIOTYPE: Ohio State University Geol. Mus. no. 18896, locality 1a.

Also occurs at locality 2a.

PONDERODICTYA UNICORNIS (Van Pelt)
Plate 10, figures 30, 31

Primitiopsis unicornis Van Pelt 1933, Jour. Paleontology, vol. 7, no. 3, p. 326, pl. 39, figs. 23–28. Bell shale, Middle Devonian, Michigan.

Ponderodictya unicornis Coryell and Malkin 1936, Am. Mus. Novitates, no. 891, p. 16, figs. 31, 31a. Hamilton formation, Arkona, Ontario.

The great difficulties encountered in the classification of the variable types of the so-called *Primitiopsis punctulifera* group is apparent to all who have attempted to study them. Coryell and Malkin have done much to clarify this situation, and regardless of the senior author's previous interpretation of some of the forms, in this study we concur with them in recognizing the above species as encompassing most of the related forms.

All of the specimens examined from the Plum Brook shale show the characteristic features of the genus, i.e., the arcuate hinge, larger left valve, and strongly reticulate surface. They have only one well-developed spine on the right valve, in the postventral region. Only one specimen has a postventral spine on the left valve. Three specimens have a low, curving tubercle near the anterior end of the right valve. There is considerable variation in the strength of the surface markings; in general the smaller specimens seem to have coarser reticulations. Such differences seem to represent no more than individual variations. It is possible that the larger specimens are female forms.

PLESIOTYPES (2): Ohio State University Geol. Mus. no. 18897, locality 3d.

Also occurs at localities 1a, and 3g.

Family QUASILLITIDAE Coryell and Malkin

Genus QUASILLITES Coryell and Malkin

QUASILLITES OBLIQUUS Coryell and Malkin
Plate 10, figures 32–34

Quasillites obliquus Coryell and Malkin 1936, Am. Mus. Novitates, no. 891, p. 18, figs. 36, 36a. Hamilton formation, Ontario.

Several finely preserved specimens are referred to this species. The anteroventral spine is much less robust, but apart from that, the other features are essentially characteristic of the species. The subrhomboidal shape and the parallelism of the dorsal and ventral margins are best seen in interior valve views. The shell is thick and the contact of the valves is wide, the right being the larger of the two.

Length of a right valve, measured at midheight, 0.87 mm.; height in middle of posterior half, 0.46 mm.

PLESIOTYPES (3): Ohio State University Geol. Mus. no. 18899, locality 3g.

Also occurs at localities 1a, 3d, and 3f.

QUASILLITES? PSEUDOBREVISPINATA
Stewart and Hendrix, n. sp.
Plate 10, figures 35–37

Carapace subrhomboidal in outline; greatest height central or in middle of posterior half; greatest thickness in middle of posterior half; greatest length approximately midway between dorsal and ventral margins to slightly dorsad of middle; hinge line apparently straight, channelled along middle third; dorsal and ventral margins slightly convex to straight; posterior margin broadly rounded with cusp-like marginal spine at midheight; anterior margin less broadly rounded, most extended in dorsal half.

Valves distinctly convex; right valve slightly larger, overlapping left except along middle portion of hinge; details of hingement not observed.

Surface of valves with fine anastomosing lines, generally longitudinal but in some places more or less transverse; round smooth central spot faintly indicated on some specimens. Small body spine present on each valve just above anteroventral margin, usually extending forward to edge of shell; low shoulder occurs near posterior margin of each valve, most pronounced on left.

Length of mature specimen, measured at midheight, 0.70 mm.; height, measured centrally, 0.43 mm.; thickness, measured anteriorly, 0.33 mm.

The position of this species in the genus *Quasillites* is open to question. The surface markings are not nearly so distinct and the anteroventral spine is much less strongly de-

veloped than in most species of the genus. In some respects the form resembles species of the genus *Burlella*, but it lacks the characteristic anterior U-shaped depression. It resembles most closely *Burella brevispinata* Stewart, differing only in the smaller body spines and the cusp-like posterior marginal spine. It may be necessary to erect a new genus for this form.

This species is the most abundant and most widely distributed of all the ostracodes collected from northern Ohio.

SYNTYPES (3): Ohio State University Geol. Mus. no. 18872, locality 3b.

Also occurs at localities 1a, 2b, 3a, 3c, 3f, 3g, and 4a.

Genus ERIELLA Stewart and Hendrix, n. gen.

Carapace thick, sturdy, sub-rectangular in outline; hinge essentially straight; left valve slightly overlapped by right on centroventral margin; contact margin wide; both valves flattened posteriorly forming keel; surface coarsely, symmetrically reticulate, reticulations forming more or less concentric pattern around center of each valve; small circular pit in center of each valve.

GENOTYPE: *Eriella robusta* Stewart and Hendrix, n. sp.

ERIELLA ROBUSTA Stewart and Hendrix, n. sp.
Plate 10, figures 38, 39

Shell subrectangular in outline, thick; greatest height in posterior fourth; greatest length approximately midway between dorsal and ventral margins; greatest thickness in anterior half; hinge line straight, sulcate with dorsal margins of both valves rising above it; anterior margin most extended in upper half, narrowly rounded; posterior margin broadly, evenly rounded; dorsal margin slightly convex; ventral margin slightly sinuate at midlength.

Valves moderately convex, essentially equal except for slight overlap of right on centroventral margin; posterior surface descends rapidly to margin forming prominent shoulder, shell extending keel-like beyond shoulder; anterior surface also slopes steeply but does not form so prominent a shoulder and sudden drop is closer to margin; two nodose extensions pointing anteriorly present in anteroventral regions of both valves.

Surface marked by coarse, rectangular reticulations, arranged concentrically about center of each valve, roughly paralleling margins; shallow pit in center of each valve.

Length, measured slightly dorsad of mid-height, 0.72 mm.; height, measured in posterior half, 0.41 mm.; thickness, measured in anterior half, 0.32 mm.

This species is represented by a number of well preserved specimens. There seems to be no similarly described species with which it needs to be compared. The surface markings and sharply defined posterior shoulder and keel are distinctive.

GENOTYPE AND PARATYPE: Ohio State University Geol. Mus. no. 18898, locality 4a.

Also occurs at localities 3e and 3g.

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REFERENCES

BASSLER, R. S., and KELLETT, BETTY, 1934, Bibliographic index of Paleozoic Ostracoda: Geol. Soc. America, Spec., Papers 1.

COOPER, G. A., 1930, Stratigraphy of the Hamilton group of New York: Am. Jour. Sci., ser. 5, vol. 19.

——, 1933, The Hamilton group in eastern New York: idem, vol. 26.

CORYELL, H. N., and MALKIN, D. S., 1936, Some Hamilton ostracodes from Arkona, Ontario: Am. Mus. Novitates, no. 891.

GRABAU, AMADEUS, 1915, The Olentangy shale of central Ohio and its stratigraphic significance: Geol. Soc. America Bull. 26, p. 112.

STAUFFER, C. R., 1916, The relationships of the Olentangy shale and associated Devonian deposits of northern Ohio: Jour. Geol., vol. 24, pp. 476–487.

——, 1938, Conodonts of the Olentangy shale: Jour. Paleontology, vol. 12, no. 5, pp. 411–443.

STEWART, GRACE A., 1936, Ostracodes of the Silica shale, Middle Devonian of Ohio: Jour. Paleontology, vol. 10, no. 8, pp. 739–763.

STUMM, ERWIN C., 1942, Fauna and stratigraphic relations of the Prout limestone and Plum Brook shale of northern Ohio: Jour. Paleontology, vol. 16, no. 5, pp. 549–563.

TURNER, MARY C., 1939, Middle Devonian Ostracoda from oil wells in southeastern Ontario: Bull. Am. Paleontology, vol. 25, no. 88, pp. 1–32, pl. 1.

VAN PELT, HERBERTA L., 1933, Some ostracodes from the Bell shale, Middle Devonian of Michigan: Jour. Paleontology, vol. 7, no. 3, pp. 325–342.

WARTHIN, A. S., JR., 1937, Type invertebrate fossils of North America (Devonian) Beyrichiacea: Wagner Free Institute of Science, Pub. Philadelphia.

——, 1934, Common Ostracoda from the Traverse Group: Michigan University, Contrib. Mus. Paleontology, vol. 4, no. 2, pp. 205–226.

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OSTRACODA OF THE OLENTANGY SHALE, FRANKLIN AND DELAWARE COUNTIES, OHIO

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ABSTRACT.—Twenty-nine species of ostracodes from the Olentangy shale of Franklin and Delaware counties are described. These are distributed through 11 families and 15 genera, 5 of the latter being described as new. With the exception of two species, *Ctenoculina cicatricosa* (Warthin), and *Bythocypris lucasensis* Stewart, the entire fauna is new. A shoet introduction summarizes opinions on the stratigraphic and faunal relations of the shale. The ostracode fauna suggests an Upper Devonian age.

THE Olentangy shale crops out more or less continuously along the Olentangy River for a distance of about 25 miles from the vicinity of Arcadia Avenue in North Columbus, Franklin County, to Delaware, Delaware County. The outcrops are best seen along the east bank of the river, and the tributary ravines from both east and west. A single good exposure is found along the Scioto River valley on Slate Run directly west of North Columbus.

In 1874 N. H. Winchell named the Olentangy shale from the exposures at Delaware. Here the formation is typically soft bluish gray clay shale, 30 to 35 feet thick, which weathers to gray clay. It contains layers of gray and bluish limestone concretions as well as continuous layers of dark-brown shale. The concretions are most abundant near the base of the formation. The dark shale occurs only in the upper half of the formation, is most abundant near the top and is similar to the overlying Ohio shale.

The Olentangy shale was considered to be practically nonfossiliferous by Winchell, but collecting over a period of years has yielded a dozen or so species of megascopic fossils, and numerous microscopic species. Because of the seemingly unfossiliferous character of the shale Winchell did not attempt to extend the use of the term outside the confines of the two counties.

The Olentangy shale lies below the Ohio black shale sequence and overlies the Delaware limestone disconformably. The relations of the Olentangy shale to the Plum Brook shale of Erie County in northern Ohio, and to the bluish beds at the base of the Ohio shale in the southern part of the state still remains a controversial matter.

Stauffer (1909) first extended the name Olentangy shale to the soft bluish Hamilton shale in Erie County, considering it to be the lower, sparingly fossiliferous phase of the latter formation. In its most northern outcrop he recognized the Olentangy shale as forming the base of the Hamilton beds along the Ausable River north of Lake Erie in Ontario; then he considered it to outcrop intermittently southward in Ohio, first in Erie County, then in Delaware and Franklin counties, and finally in Ross County and at intervals to the Ohio River and southward into Kentucky. In Ohio these shales vary in thickness from a maximum of about 85 feet in the north to a few inches in the south. In northern and central Ohio, according to his interpretation, the Olentangy shale overlies the Delaware limestone, but because of overlap southward it finally comes to rest directly on the Niagaran series in southern Ohio. Stauffer believed that the upper boundary is controlled by an unconformity and that the upper Hamilton beds are gradually cut out southward by overlap of the Huron or basal portion of the Ohio black shale.

Grabau (1917) interpreted the stratigraphic relations of the Olentangy shale differently. He believed that the Hamilton shale of Erie County pinches out rapidly

southward, and that the Olentangy shale of central Ohio is a bluish shale phase at the base of the Ohio shale of later Devonian age. Lamborn (1927) accepted this idea and considered the several outcrops of bluish shale near the Ohio River to be basal Ohio shale also. Westgate (1926) stressed the conformable appearance of the Ohio and Olentangy shales in the type section of Delaware County, and in addition reported the presence of layers of bluish gray shale entirely similar to the Olentangy, well up in the Ohio shale. This interbedded and transitional character of the two shales is further revealed in the black shale layers in the upper part of the Olentangy shale. Westgate attributed the slightly undulating character of the contact to a gentle warping caused largely by the growth of large limestone concretions near the contact.

Stauffer (1916), pp. 486, 487) maintained that at certain places there is a sharp and irregular contact between the Olentangy and Ohio shales suggesting a disconformity. He discounts the importance of the black shale layers in the upper part of the Olentangy formation, and points out that bands of black or brown shale layers are found in beds of Hamilton age in western New York similar to the Geneseo some distance above. He suggests that the brown shale layers of the Olentangy probably resemble the brown shale layers interbedded with the Delaware limestone of the same region as much as they do the typical Ohio or Huron shale. The writers do not concur in this opinion.

Stauffer (1938, p. 1078) listed a fauna from the Olentangy shale on Slate Run, Franklin County, which he considered to be Middle Devonian. Of the dozen or more forms recorded, only five species were identified without question. Of these, three presumably are known only from the Middle Devonian: *Aulopora serpens*, *Productella spinulicosta*, and *Tentaculites bellulus*. The other two, *Strophalosia truncata*, and *Stylioliná fissurella*, range into the Upper Devonian, the latter being especially characteristic of the Geneseo. In our opinion the Middle Devonian age of this fauna is somewhat questionable. However, Stauffer (1938) found that the conodonts undoubtedly resemble those in the Plum Brook shale in Erie County and the bluish shale in southern Ohio. There seems to be a close similarity especially with the latter because of 26 species collected in south-central Ohio all but one were found in central Ohio.

Baker (1942) discussed the age relations of the Olentangy shale and a 'depauperate' fauna and flora collected mostly from the limestone layers in the formation. Of the 20 or more forms which he recognized probably the most significant in establishing the age of the shale is the genus *Manticoceras*, a goniatite which is considered to be an Upper Devonian index genus the world over. Other forms of distinctly Upper Devonian type are *Melocrinus clarkei* previously known only from the Geneseo and Portage of New York, *Chonetes minutus* from the Chagrin of northern Ohio, and *Anaptychus? emersoni* from the Upper Devonian black shales of Indiana, Ohio, Kentucky, and New York. On the other hand, Baker included in the list some species that are very characteristic of the Middle Devonian. *Reptaria stolonifera* and *Ambocoelia umbonata* are common in the Silica shale, the later species being extremely abundant in one layer. *Tornoceras uniangulare* occurs in both the Plum Brook and Silica shales. A significant fact noted by Baker and likewise observed by the writers is that the black shale layers in the Olentangy contain much the same flora and fauna as the Ohio shale above. Of the forms probably plant spores, *Sporangites huronensis*, are the most noticeable. From both stratigraphic and faunal evidence Baker concluded that the Olentangy shale should be regarded as a basal phase of the Ohio shale as interpreted by Grabau.

Cooper et al (1942) placed the Olentangy shale well up in the Senecan although they cite no supporting evidence.

Because ostracodes were known to occur in the Olentangy shale the present study was undertaken in the hope that they might yield additional light on its age relations, besides giving a more complete picture of its fauna.

Twenty-nine samples of shale were collected from various outcrops and 13 were found to contain ostracodes. In some samples only one species has been recognized, others, however, have yielded a fairly rich fauna. The most abundantly fossiliferous sample is from locality 2a, Bartholomew

Run, from which 27 species were recovered. Practically all the species recognized in the formation are present there.

The writers feel that future collecting will greatly augment this list. A great many specimens collected have not been identified because of poor preservation. Two types of secondary replacement commonly occur which often obliterate the surface characters. The most common is replacement by pyrite. In most specimens of this type the center is filled with crystalline pyrite. In only one species has the pyrite been found to form pseudomorphs of the shell; in all other pyritic specimens the crystals penetrate to the surface and the outlines and markings are destroyed. Other specimens are covered with a thick deposit of calcite which destroys the surface characters. Most specimens collected at the type section are preserved in this way and their identification is more or less uncertain. Likewise at Camp Lazarus and Deep Run most specimens are heavily coated with calcite. Some of the best preserved specimens were obtained from the Bartholomew Run samples.

The ostracodes of the Olentangy shale are almost all undescribed forms; of 29 species all but two are new. However, 5 species from Lewis Center Run, locality 4a, tentatively identified with forms occurring in the Plum Brook shale, are not included in this report. These are: *Burlella brevispinata* Stewart, *Quasillites? pseudobrevispinata* Stewart and Hendrix, *Punctoprimitia simplex transversa* Stewart and Hendrix, *Ponderodictya ohioensis* Stewart, and *Quasillites obliquus* Coryell and Malkin. Only two other species were found at this locality: *Bythocypris lucasensis* Stewart, and *Ctenoculina cicatricosa* Warthin. More intensive collecting should be undertaken in this region.

The remainder of the fauna does not seem to resemble any other Middle Devonian fauna with which the writers are familiar. Typical Hamilton forms are not represented. Even the ubiquitous *Ponderodictya unicornis* Van Pelt has not been recognized. The most common and widely distributed species are *Coelonella granulifera* n. sp. and *C. punctulifera* n. sp. They have been found in 9 of the samples collected and invariably occur together. *Richterina symmetrica*, n. sp. is the only representative of a European genus so far recognized in North America. This genus appears to be restricted to the Upper Devonian.

The occurrence of representatives of the family Glyptopleuridae in the new genus *Franklinella* is of interest. This family has not been found previously below the Mississippian and it is especially characteristic of that period. Species of *Franklinella* are one of the most striking elements of the fauna. They are characterized by a prominent postventral and anterodorsal spine on each valve, and by heavy transverse costae, of which the upper four unite anteriorly to form the anterodorsal spine, and the lower three to form the postventral spine.

The new genus *Senescella* of the Barychilinidae is another outstanding element of the fauna. Species of this genus are especially characterized by their old and extremely wrinkled appearance. The presence of several species of *Bairdia* is also noteworthy because this genus is extremely rare below the Mississippian. Although not numerous in individuals the fact that five species are present in a fauna of 29 is striking. Likewise, the occurrence of several species of *Amphissites* of the Kirkbyidae is of interest. Although several species have been recorded from the Devonian of North America, this genus is much more characteristic of the Mississippian and younger Paleozoic rocks.

It appears to the writers that this fauna is not a typical Hamilton assemblage such as those of the Plum Brook and Silica shales. Its composition suggests Upper Devonian, or even Mississippian age and we are not prepared at present to correlate it definitely with any known fauna of the New York section. We feel that more thorough and comprehensive collecting is required to determine more certainly the age relations of the Olentangy shale.

The following species are identified and described in this report:

Bertillonella subcircularis Stewart and Hendrix, n. gen., n. sp.
Coelonella granulifera Stewart and Hendrix, n. sp.
Coelonella punctulifera Stewart and Hendrix, n. sp.
Sansabella? curiosa Stewart and Hendrix, n. sp.
Ctenoculina cicatricosa (Warthin)
Primitia? prolifica Stewart and Hendrix, n. sp.
Kloedenella pulcra Stewart and Hendrix, n. sp.

Bissaculus bilobus Stewart and Hendrix, n. gen., n. sp.
Amphissites bernhageni Stewart and Hendrix, n. sp.
Amphissites carmani Stewart and Hendrix, n. sp.
Amphissites shafferi Stewart and Hendrix, n. sp.
Franklinella novecosta Stewart and Hendrix, n. gen., n. sp.
Franklinella novecosta obesa Stewart and Hendrix, n. var.
Franklinella septecosta Stewart and Hendrix, n. sp.
Ropolonellus? dubius Stewart and Hendrix, n. sp.
Bairdia bartholomewensis Stewart and Hendrix, n. sp.
Bairdia delawarensis Stewart and Hendrix, n. sp.
Bairdia lenticulata Stewart and Hendrix, n. sp.
Bairdia pseudomagna Stewart and Hendrix, n. sp.
Bairdia unica Stewart and Hendrix, n. sp.
Bythocypris lucasensis Stewart (?)
Thrallella mimica Stewart and Hendrix, n. gen., n. sp.
Thrallella phaseolina Stewart and Hendrix, n. sp.
Thrallella susanola Stewart and Hendrix, n. sp.
Richterina symmetrica Stewart and Hendrix, n. sp.
Senescella crassimarginata Stewart and Hendrix, n. gen., n. sp.
Senescella marginaspinata Stewart and Hendrix, n. sp.
Senescella longaeva Stewart and Hendrix, n. sp.
Senescella longaeva deflecta Stewart and Hendrix, n. var.

LOCALITIES AND OCCURRENCE OF SPECIES

Franklin County

1. Slate Run. The run which enters Scioto River from the east, 2½ miles north of the storage dam; Dublin Quadrangle, T 1 N, R 19 W, NW¼ NW¼(1) of the township.

1a—From 0 to 1 feet below a 4-inch fairly continuous limestone layer which forms the caprock of a 2-foot shale layer about 20 feet below the Ohio shale contact; *Bertillonella subcircularis, Coelonella granulifera, C. punctulifera, Amphissites bernhageni, A. carmani, A. shafferi, Thrallella mimica, Senescella crassimarginata, S. marginaspinata.*

Delaware County

2. Bartholomew Run. One mile north of the Franklin-Delaware County line in Delaware County; Dublin Quadrangle, T 3 N, R 19 W, E½ SW¼(4) of the township. The run enters Olentangy River from the west and heads near Powell.

2a—From 10 feet 2 inches to 12 feet 1 inch above the base of the Olentangy formation, including a 4-inch continuous bluish limestone at the bottom and a 3-inch dark brown shale layer at the top, 80 yards north of the confluence of the main tributaries. This is the most abundantly fossiliferous sample collected: *Bertillonella subcircularis, Coelonella granulifera, C. punctulifera, Sansabella? curiosa, Primitia? prolifica, Kloedenella pulcra, Bisacculus bilobus, Amphissites bernhageni, A. carmani, A. shafferi, Franklinella novecosta, F. novecosta* var. *obesa, F. septecosta, Ropolonellus? dubius, Bairdia bartholomewensis, B. delawarensis, B. lenticulata, B. pseudo-magna, B. unica, Thrallella mimica, T. phaseolina, T. susanola, Richterina symmetrica, Senescella crassimarginata, S. marginaspinata, S. longaeva, S. longaeva* var. *deflecta.*

2b—From 4 inches above and below a 4-inch continuous bluish limestone layer 10 feet 2 inches above the base of the formation; 250 yards north of the county road corner at Tall Timbers: *Bertillonella subcircularis, Coelonella granulifera, C. punctulifera, Sansabella? curiosa, Primitia? prolifica, Amphissites bernhageni, A. carmani, A. shafferi, Franklinella novecosta, F. novecosta* var. *obesa, F. septecosta, Bairdia delawarensis, Senescella crassimarginata, S. marginaspinata, S. longaeva.*

2c—From 4 inches above and below the 3-inch black shale layer 12 feet above the base of the formation; 250 yards north of the county road corner at Tall Timbers: *Coelonella granulifera, Sansabella? curiosa, Amphissites carmani, A. shafferi, Franklinella novecosta, F. novecosta* var. *obesa, F. septecosta, Senescella crassimarginata, S. marginaspinata.*

3. Deep Run. Two and one-half miles north of the Franklin-Delaware County line in Delaware County; Dublin Quadrangle, T 3 N, R 18 W, NW¼ SE¼ (3) of the township. The run enters Olentangy River from the east.

3a—Immediately above and below a nodular limestone layer in the lower portion of the Olentangy formation: *Amphissites berngaheni, A. carmani, A. shafferi.*

4. Lewis Center Run. This run trends directly west to Olentangy River from Lewis Center, a former stop on the abandoned Columbus, Delaware and Marion Electric Railroad; Dublin Quadrangle, T 3 N, R 19 W, NW¼ NE¼ (2) of the township.

4a—From above and below a nodular limestone layer about 4 feet below the top of the formation; on the north fork about 200 yards above the confluence: *Ctenoculina cicatricosa, Bythocypris lucasensis.*

5. Camp Lazarus Run. The run which enters Olentangy River from the east at Camp Lazarus 1¾ miles south of Stratford; Dublin Quadrangle, T 4 N, R 19 W, SE¼ township.

5a—From directly below a 6-inch continuous limestone layer in the bed of the stream 150 yards west of the triple fork of the stream: *Coelonella granulifera, C. punctulifera, Sansabella? curiosa, Amphissites shafferi.*

5b—From 0 to 8 inches above a thin continuous limestone layer a few feet below 5a: *Bertillonella subcircularis, Coelonella punctulifera, Richterina symmetrica.*

6. Delaware. The east bank of Olentangy River, one-fourth mile south of the old Big Four Railroad bridge; Delaware Quadrange, T 4 N, R 19 W, NW¼ NE¼(1) of the township; and T 5 N, R 19 W, SW¼ SE¼(4) of the township. The type section for the Olentangy shale.

6a—From just above a 0–6-inch nodular limestone layer 7 feet 4 inches above the base of the formation: *Coelonella granulifera, Ctenoculina cicatricosa.*

6b—From 5 inches above to 5 inches below a 0–5-inch nodular limestone layer 8 feet 6 inches above the base of the formation: *Amphissites carmani.*

6c—From the 1-inch dark brown shale layer 17 feet 7 inches above the base of the formation and to 2 inches below it: *Coelonella granulifera.*

6d—Immediately above and below the 3-inch limestone lens 22 feet 8 inches above the base of the formation: *Coelonella granulifera.* Additional forms only tentatively identified because of poor preservation are: *Coelonella punctulifera? Amphissites bernhageni?, Ponderodictya ohioensis?.*

6e—From 4 inches above and below a nodular limestone layer 12 feet 7 inches above the base of the formation. Ostracodes from this sample not identified.

SYSTEMATIC DESCRIPTIONS

Family LEPERDITELLIDAE Ulrich and Bassler

Genus BERTILLONELLA Stewart and Hendrix, n. gen.

Carapace thick, subcircular to subreniform in outline; hinge arcuate; valves strongly convex, equal; surface marked by concentric, fingerprint-like ridges.

GENOTYPE: *Bertillonella subcircularis* n. sp.

This simple, unsulcated ostracode is placed only provisionally in the family Leperditellidae because its distinctive surface sculpture is unlike that of any other genus of the family.

BERTILLONELLA SUBCIRCULARIS Stewart and Hendrix, n. sp.

Plate 11, figures 1, 2

Carapace thick, gibbous, subcircular to subreniform in outline; highest midway between ends, longest midway between dorsal and ventral margins; thickest centrally; dorsal margin strongly arcuate, ventral margin concave in middle; ends subequally rounded, posterior slightly broader. Proper orientation not apparent because of nearly circular outline, our interpretation questionable.

Valves apparently equal; perfect specimens show no overlap but in some slightly distorted specimens one valve has been pushed over other along margins. Details of marginal contact, especially along hinge, somewhat indefinite.

Surface ornamentation consists of concentric ridges centering in middle, resembling fingerprint.

Size quite variable, larger specimens females. Dimensions of average smaller specimen: length midway between dorsal and ventral margins, 0.84 mm.; height, measured centrally, 0.64 mm.; thickness, measured centrally 0.52 mm. A large circular specimen measures 1.16 mm. in length, 0.93 mm. in height, and 0.73 mm. in thickness.

This is one of the more abundant species in the Olentangy shale. It differs from any described ostracode species known to the authors in its novel fingerprint-like markings. Although variation in the shape and size is considerable there seems to be no consistent reason for recognizing more than one species.

HOLOTYPE AND PARATYPE: Ohio State University Geol. Mus. 18851, locality 2a.

Also accurs at localities 1a, 2b, and 5b.

Genus COELONELLA Stewart

COELONELLA GRANULIFERA Stewart and Hendrix, n. sp.

Plate 11, figures 3–5

Carapace thick, elliptical to subovoid in outline; greatest height in posterior fourth of shell; greatest thickness in anterior half; greatest length approximately midway between upper and lower margins; hinge line straight, occupying entire dorsal margin; ventral margin sulcate in central area, rising anteriorly; dorsal margin almost straight in

lateral view, depressed in central area into distinct sulcus, rising towards ends, anterior rise being more abrupt; anterior end narrowly rounded, most extended in dorsal half; posterior end broadly, evenly rounded with broad cusplike marginal spine at midheight.

Shell highly convex to tumid, inequivalved, right valve overlapping left except along hinge; overlap greatest ventrally and along the anterodorsal slope; edge of right valve grooved for reception of smaller left valve.

Surface finely reticulate to granulose; rounded muscle spot of clearer shell material in the center of each valve evident in most specimens.

Dimensions of typical specimen: length, measured at midheight, 0.81 mm.; height, measured through middle of posterior half; 0.52 mm.; thickness, measured through anterior half, 0.46 mm.

In the channelled character of the dorsal margin, and in the character of the overlap of the right valve this species seems to fill the requirements of the genus *Coelonella* better than any other. It is further distinguished by the cusplike tooth in the middle of the posterior margin, and in the sulcate ventral margin. *Coelonella granulifera* and *C. punctulifera* are very similar in their characters but the former differs in being relatively shorter, and in having a more granulose type of shell structure. Both species are the most abundant and widespread of the ostracodes collected, and invariably occur together.

SYNTYPES (3): Ohio State University Geol. Mus. 18854., locality 2a.

Also occurs at localities 1a, 2b, 2c, 5a, 6a, 6c, and 6d.

COELONELLA PUNCTULIFERA Stewart and Hendrix, n. sp.
Plate 11, figures 6–8

Shell thick, subovoid to elliptical in outline; greatest height in middle of posterior half; greatest length midway between upper and lower margins; greatest thickness in middle of anterior half; hinge line straight, occupying entire dorsal margin; ventral margin sulcate along central part, rising forward; dorsal margin almost straight in lateral view, depressed into sulcus throughout central part along contact of valves, rises towards ends; anterior margin narrowly rounded, most extended in upper half; posterior margin broadly, evenly rounded, produced into cusp-like spine at midheight.

Shell inequivalved, right valve larger, overlapping left strongly on all but sulcate portion of dorsal margin; grooved along margin for reception of smaller left valve.

Surface punctate; central muscle spot on each valve scarcely discernible.

Dimensions of typical specimen: length, measured at midheight, 0.83 mm.; height, measured in middle of posterior half, 0.46 mm.; thickness, measured in middle of anterior half, 0.43 mm.

This species is generally well preserved, and seems to be quite constant in its characters.

SYNTYPES (3): Ohio State University Geol. Mus. 18855, locality 2a.

Occurs also at localities 1a, 2b, 5a, and 5b.

Genus SANSABELLA Roundy
SANSABELLA? CURIOSA Stewart and Hendrix, n. sp.
Plate 11, figures 9, 10

Carapace moderately convex, subrectangular in lateral view; height practically uniform throughout length of shell; thickness slightly greater in middle of anterior half; length greatest midway between upper and lower margins; hinge line straight, occupying entire dorsal margin; dorsal margin straight, depressed into shallow sulcus along hinge; ventral margin slightly convex; ends broadly, evenly rounded. Almost bilaterally symmetrical except in dorsal view when one end is seen to be slightly thicker. Thicker end interpreted as anterior.

Shell inequivalved, left valve larger, overlaps right slightly on ventral margin and at ends; left valve with slight groove on free margins into which smaller right valve fits; details of hingement not observed.

Surface finely granulose or faintly reticulate. Faint submarginal ridge parallels all but dorsal margin. Small node present just below dorsal margin in anterodorsal region of each valve.

Dimensions of typical specimen: length, measured between upper and lower margins, 0.61 mm.; height, measured centrally, 0.38

mm.; thickness, measured anteriorly, 0.26 mm.

Among the specimens collected separate valves are uncommon, only one poorly preserved valve having been found, which shows details of the hinge structure very poorly.

This form does not resemble very closely any described species of the genus *Sansabella*. Its position in this genus is questionable because it does not have the same sort of tonguelike overlapping hinge structure, but it seems to fit the requirements of the genus very well.

SYNTYPES (2): Ohio State University Geol. Mus. 18856, locality 2a.

Also occurs at localities 2b, 2c, and 5a.

Family TETRADELLIDAE Swartz
Genus CTENOCULINA Bassler
CTENOCULINA CICATRICOSA (Warthin)
Plate 11, figure 11

Tetradella cicatricosa Warthin, 1934, Michigan University, Contrib. Mus. Paleontology, vol. 4, no. 12, p. 209, pl. 1, figs. 4–6.
Ctenoculina Bassler, 1941, Washington Acad. Sci., Jour., vol. 31, no. 1, p. 22.

Only one specimen of the left valve of a young male is certainly referable to this species. It appears to conform in all respects with the general characteristics of the species except that the presence of an incipient fifth ridge is suggested in the posterior region near the ventral margin next to the last transverse ridge.

PLESIOTYPE: Ohio State University Geol. Mus. 18888, locality 4a.

Also occurs at locality 6a (?).

Family PRIMITIIDAE Ulrich and Bassler
Genus PRIMITIA Jones and Holl
PRIMITIA? PROLIFICA Stewart and Hendrix, n. sp.
Plate 11, figures 12–14

Carapace large, suboval to subquadrate in outline; greatest height central or in about middle of anterior half of shell; posterior half of maximum thickness or equal in thickness to anterior portion; hinge line straight to slightly curved, occupying middle third of dorsal margin; both dorsal and ventral margins straight to slightly convex; upper portion of posterior margin narrowly rounded, lower part more broadly rounded; anterior margin evenly, broadly rounded.

Shell depressed convex; valves equal; apparently meeting in even contact all round without apparent overlap. Hingement probably consisting of grooved contact along middle third of dorsal margin but no separate valves have been seen and this is not certain.

Surface marked by very faint lines extending lengthwise of shell. Strongly forward-curving sulcus extends upward from well-defined pit near center of valve, bifurcates above, one part curving forward, other backward.

Two types apparently present: larger (female) form with dorsal and ventral margins almost parallel, and smaller more oval (male) form.

Dimensions of larger female: length 1.45 mm.; height 0.93 mm.; thickness 0.58 mm.; thickness 0.35.

This species is abundantly represented in two samples. Its reference to this genus is doubtful.

SYNTYPES (3): Ohio State University Geol. Mus. 18878. locality 2a.

Also occurs at locality 2b.

Family KLOEDENELLIDAE Ulrich and Bassler
Genus KLOEDENELLA Ulrich and Bassler
KLOEDENELLA PULCRA Stewart and Hendrix n. sp.
Plate 11, figure 15

Carapace subquadrate in outline; highest in posterior half, longest slightly below middle, thickness practically uniform throughout entire length; hinge straight, occupying entire dorsal margin; ventral margin concave in central part; dorsal margin slightly sinuous, rising backward; postdorsal angle broadly rounded, merging into broadly rounded posterior end; anterior margin more narrowly rounded, forming acute angle with dorsal margin; free margins of valve minutely evenly serrate, serrations strongest on ventral edge.

Overlap undetermined; well-developed internal flange roughly parallels all margins but central part of dorsum suggesting that right valve is larger and overlapping; hinge

with slight groove and small posterior tooth-like extension; shell minutely punctate. Median backward-curving sulcus extends downward from dorsal margin, terminates in distinct pit about one-third distance to venter; second round pit or depression below this sulcus and just below middle of shell. Shorter sulcus, constricted ventrally, present just posterior to middle sulcus, terminates in small pit. Valve thus divided into three lobes, anterior largest, bulging slightly above anterodorsal margin.

Dimensions: length, measured slightly below midheight, 0.89 mm.; height, measured in middle of posterior half, 0.52 mm.

This species is represented by a single right valve which is so perfectly preserved that it appears like a recent form. It resembles most closely *K. pennsylvanica* (Jones), 1889, having the sulci approximately in the same positions, and a similar anterior bulge above the dorsal margin. It differs, however, in the presence of the pit below the median sulcus, and the strongly pitted character of the surface.

HOLOTYPE: Ohio State University Geol. Mus. 18859, locality 2a.

Family KIRKBYIDAE Ulrich and Bassler
Genus BISACCULUS Stewart and Hendrix n. gen.

Small, straight-hinged carapace, semiovoid to subelliptical in outline; shell inequivalved, hingement simple, valves thin where not modified by nodes or swellings; sulcus well-defined, oblique, bounded ventrally by conspicuous, bulbous ridge. In female specimens posterior end greatly thickened to accommodate two large circular loculi in each valve; male dimorph modified by at least one postventral spine; surface granulose or finely punctate.

GENOTYPE: *Bisacculus bilobus* Stewart and Hendrix.

This genus is proposed for one new species and it may be necessary to expand its definition if other related species are discovered. It is very close to *Tetrasacculus* Stewart 1936, but differs in the occurrence of two brood pits in the female instead of four, and in the termination of the sulcus ventrally by a conspicuous bulge. It also resembles *Parabolbina* Swartz, 1936, but the sulcus is different, the ventral bulge below is much more pronounced, spines are lacking in the female, and the wide posterior with its loculi does not possess even a suggestion of a frill. The writers interpret the sulcus as being behind the middle of the valve, with the loculi at the posterior end, assuming an orientation similar to that of *Tetrasacculus*.

BISACCULUS BILOBUS Stewart and Hendrix, n. sp.
Plate 11, figures 16–18

Carapace semiovoid to subtrapezoid in lateral view; in dorsal aspect subtrigonal; greatest length about midway between upper and lower margins; greatest height and thickness in anterior half; dorsal margin straight, cardinal angles round, posterior more acute; hinge-line straight, extending length of shell, apparently grooved, but features not definitely determined; ventral margin strongly convex; posterior margin somewhat more broadly rounded than anterior which is most protuberant in upper half.

Valves slightly unequal, right valve larger, overlapping left value on free margins; hingement at contact of dorsal margins of both valves; shallow sulcus slightly posterior to middle of shell extends backward and downward, open dorsally; shell swollen below forming conspicuous bulbous ridge approximately parallel to sulcus, thickest in this part. Sulcus terminated on either side posteriorly in female specimens by two large circular loculi or brood chambers; male specimens with blunt postventral spine. Entire surface finely granulose.

Dimensions of average female specimen: length, measured midway between upper and lower margins, 0.64 mm.; height, measured posteriorly, 0.44 mm.; thickness, measured in posteroventral portion, 0.31 mm. Dimensions of smaller male specimen: length 0.49 mm.; height 0.29 mm.; thickness 0.26 mm.

Five complete specimens, one a male, and a separate valve have been found. This species is similar to *Tetrasacculus minimus* (Ulrich) from the Silica shale but the latter has four loculi instead of two, and lacks the posteroventral bulbous ridge.

HOLOTYPE AND PARATYPE: Ohio State University Geol. Mus. 18858, locality 2a.

Genus AMPHISSITES Girty

AMPHISSITES BERNHAGENI Stewart and Hendrix, n. sp.

Plate 11, figures 19–21

Carapace thick, of medium size, subrectangular to subovoid in lateral view; height greatest in middle of posterior half; length greatest in dorsal half; thickness greatest in middle; hinge straight, occupying entire dorsal margin; dorsal margin concave in side view in central portion, rising abruptly posteriorly, more gradually anteriorly; ventral margin straight, rising gradually forward to meet rounded anterior end which is most protruberant in upper half; posterior end blunt, with distinct backward swing, forming subacute angle with ventral margin.

Valves apparently equal, no suggestion of overlap noted on separate valves. Hingement a linear groove in left valve into which edge of right valve fits. Cardinal extremities terminated by small triangular flange-like projections.

Surface reticulate. Two conspicuous carinae roughly parallel free margins of each valve, converging at ends, meeting at cardinal angles; inner carina cuts across postventral portion of valve, giving truncate appearance to this part, dies out just short of cardinal angle; outer carina finely scalloped or notched along anterior and ventral margins; inner carina weaker than outer along anterior and ventral margins, but stronger along posterior margin. Large subcircular node present on each valve slightly anterior

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EXPLANATION OF PLATE 11

All illustrations approximately ×25

FIGS. *1, 2—Bertillonella subcircularis* Stewart and Hendrix, n. g., n. sp. *1*, Left valve view, and *2*, Dorsal view of two specimens. Ammonium chloride coating has obscured fine fingerprint-like markings which characterize this species. Holotype O.S.U. 18851, locality 2a. (p. 100)

3–5—Coelonella granulifera Stewart and Hendrix, n. sp. *3*, Right valve view; *4*, Interior view of right valve showing cusp-like, posterior, marginal spine; *5*, Dorsal view showing sulcus in hinge area. Syntypes (3), O.S.U. 18854, locality 2a. (p. 100)

6–8—Coelonella punctulifera Stewart and Hendrix, n. sp. *6*, Left valve view showing posterior marginal spine; *7*, Dorsal view showing sulcus along hinge area; *8*, Right valve view. Syntypes (3), O.S.U. 18855, locality 2a. (p. 101)

9, 10—Sansabella? curiosa Stewart and Hendrix, n. sp. *9*, View of right valve showing finely granulose character of surface and marginal ridge; *10*, Dorsal view, surface character obscured by grains of ammonium chloride. Syntypes (2), O.S.U. 18856, locality 2a. (p. 101)

11—Ctenoculina cicatricosa (Warthin). Left valve view of young male specimen. Plesiotype O.S.U. 18888, locality 4a. (p. 102)

12–14—Primitia? prolifica Stewart and Hendrix, n. sp. *12*, Right valve view of male dimorph, and *13*, Right valve view of large female specimen, both showing distinct forward curving sulcus; *14*, Dorsal view showing sinuosity of right valve at upper termination of sulcus. Syntypes (3), O.S.U. 18878, locality 2a. (p. 102)

15—Kloedenella pulcra Stewart and Hendrix, n. sp. Right valve with details of surface sculpture particularly well preserved. Holotype, O.S.U. 18859, locality 2a. (p. 102)

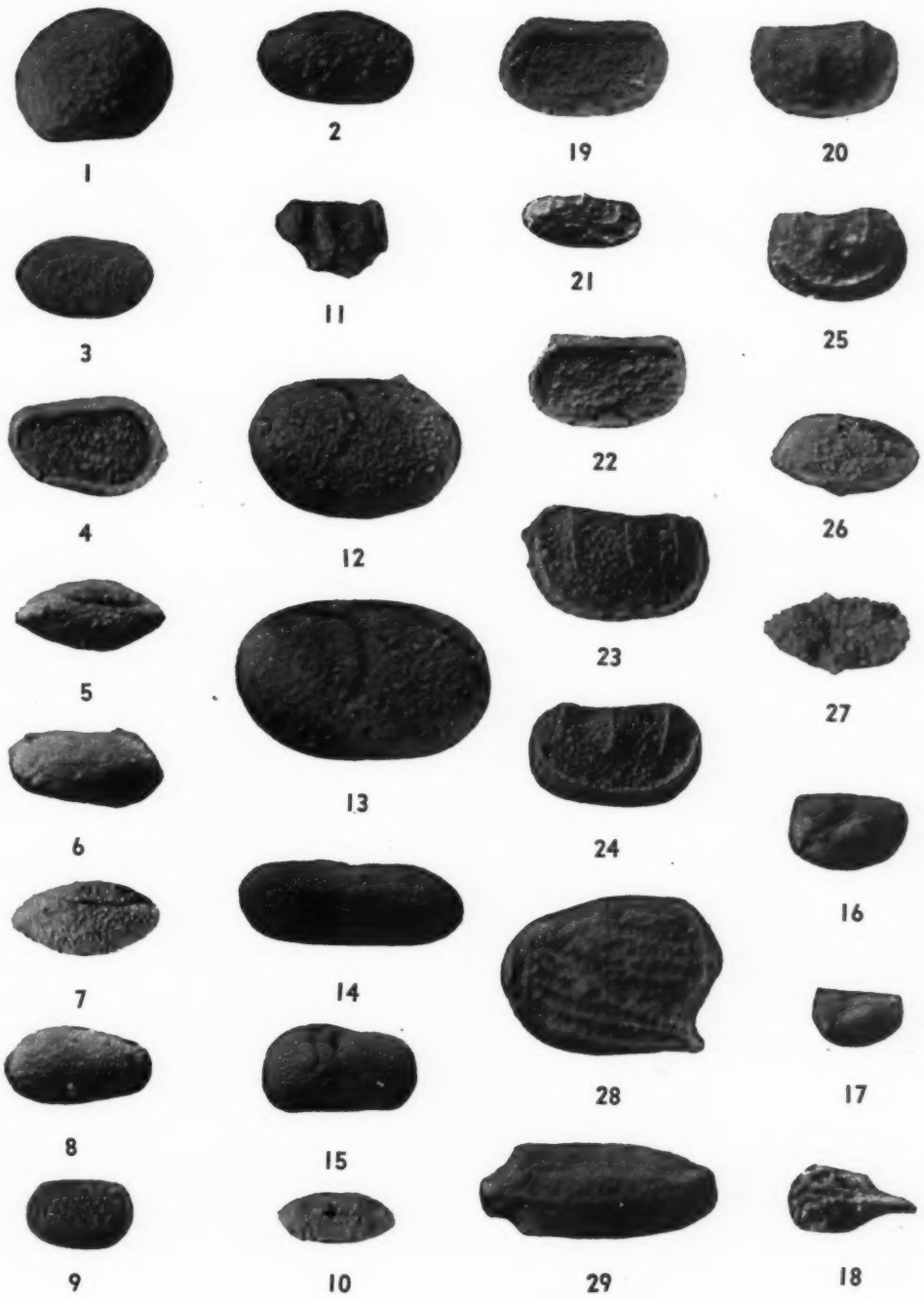
16–18—Bissaculus bilobus Stewart and Hendrix, n. g., n. sp. *16*, View of right valve of female; *17*, Left valve view of smaller male dimorph; *18*, Ventral view of female showing only one large brood pit on each valve. There is another brood pit on each valve not shown in this this view. Syntypes (3), O.S.U. 18858, locality 2a. (p. 103)

19–21—Amphissites bernhageni Stewart and Hendrix, n. sp. *19*, View of interior of left valve; *20*, Exterior of left valve showing characteristic ridges of genus and truncate character of posterior; *21*, Dorsal view of another specimen. Syntypes (3), O.S.U. 18861, locality 2a. (p. 104)

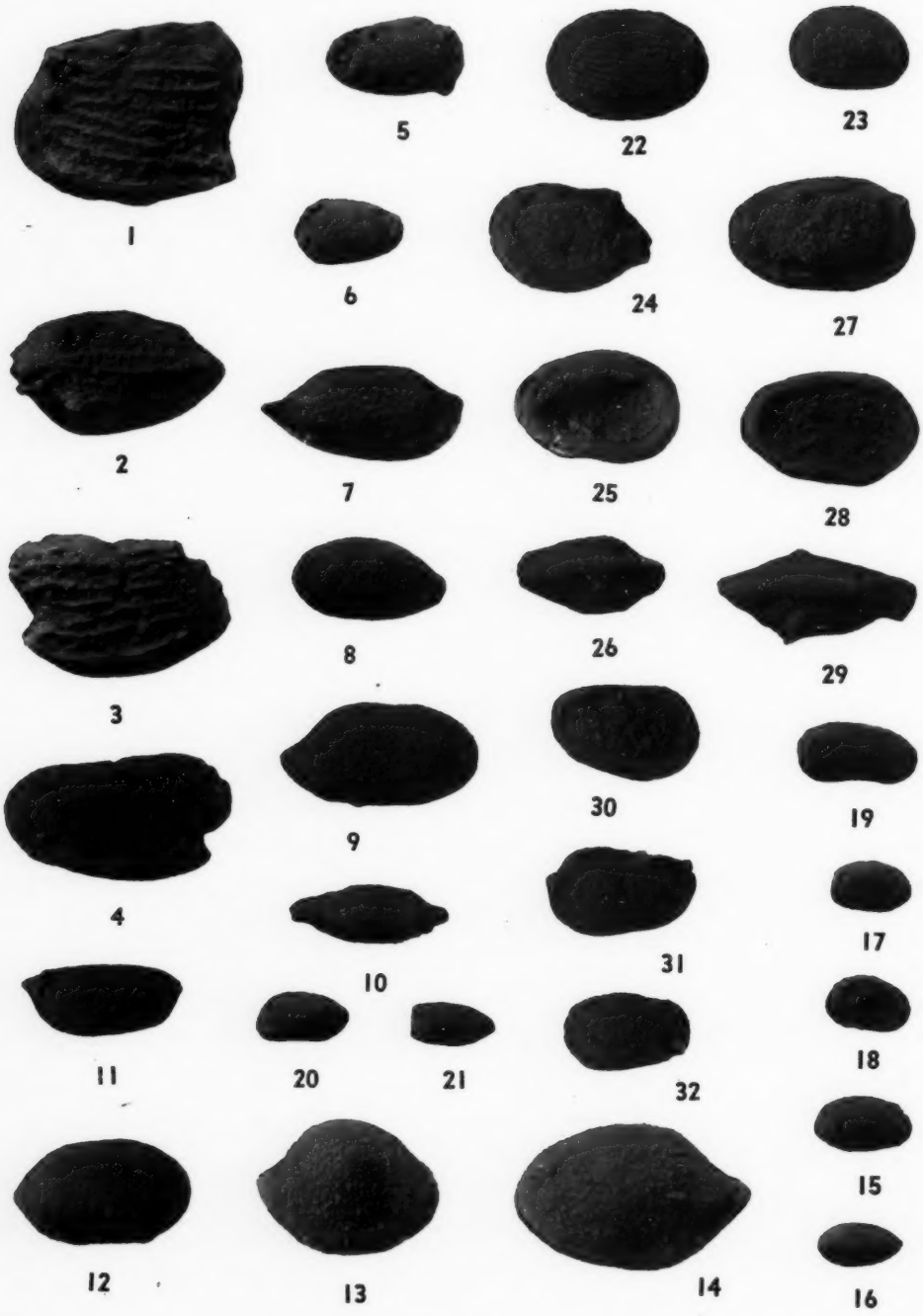
22–24—Amphissites carmani Stewart and Hendrix, n. sp. *22*, Interior view of left valve showing characteristic outline; *23, 24*, Right and left valves showing well-developed ridges and strongly punctate surface sculpture. Syntypes (3), O.S.U. 18860, locality 2a. (p. 106)

25–27—Amphissites shafferi Stewart and Hendrix, n. sp. *25*, Left valve of typical specimen showing crescentric ventral carina; *26, 27*, Ventral and dorsal views of two specimens. Syntypes (3), O.S.U. 18862, locality 2a. (p. 106)

28, 29—Franklinella novecosta Stewart and Hendrix, n. g., n. sp. *28*, Left valve showing characteristic transverse costae of genus; *29*, Dorsal view showing somewhat compressed character of valves. Holotype and paratype (2), O.S.U. 18863, locality 2a. (p. 107)



Stewart and Hendrix—Olentangy Ostracodes



Stewart and Hendrix—Olentangy Ostracodes

to center and in middle of upper half. Small pit approximately in center of shell, below node, usually formed by coalescing of two or more punctae. Vertical ridge at highest part in middle of posterior half of each valve, extending from dorsal margin to middle or below middle of shell. Ridge also present in anterior half of each valve, about same distance from subcentral node, parallels anterior margin of shell, upper end terminating at dorsal margin, lower end just below middle of shell.

Dimensions of typical left valve: length, measured midway between dorsal and ventral margins, 0.87 mm.; height, measured in middle of posterior half, 0.55 mm.

This species is similar to *A. carmani*, n. sp. and *A. shafferi*, n. sp. in having the same

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EXPLANATION OF PLATE 12

All illustrations approximately ×25

FIGS. *1, 2—Franklinella novecosta obesa* Stewart and Hendrix, n. var. *1*, Left valve exterior view of large specimen with sulcus well developed; *2*, Dorsal view showing decidedly convex character of valves. Syntypes (2), O.S.U. 18864, locality 2a. (p. 108)

3, 4—Franklinella septecosta Stewart and Hendrix, n. sp. *3*, Exterior view of right valve exhibiting greater length which distinguishes it from associated species; sulcus is also well developed; *4*, Interior of another right valve. Syntypes (2), O.S.U. 18865, locality 2a. (p. 108)

5, 6—Ropolonellus? dubius Stewart and Hendrix, n. sp. *5*, Left valve view of largest specimen; *6*, Right valve view of smaller specimen. Syntypes (2), O.S.U. 18866, locality 2a. (p. 108)

7, 8—Bairdia bartholomewensis Stewart and Hendrix, n. sp. *7*, Exterior view of right valve showing acute prolongation of posterior margin; *8*, Left valve view of cast of interior. Holotype and paratype, O.S.U. 18870, locality 2a. (p. 109)

9, 10—Bairdia delawarensis Stewart and Hendrix, n. sp. *9*, Exterior view of left valve of holotype showing characteristic shape of genus and posterior margin less extended than in preceding species; *10*, Dorsal view of cast of interior. Holotype and paratype, O.S.U. 18867, locality 2a. (p. 109)

11—Bairdia lenticulata Stewart and Hendrix, n. sp. Right valve view of only specimen showing both anterior and posterior acuminations close to dorsal margin. Holotype, O.S.U. 18869, locality 2a. (p. 110)

12—Bairdia unica Stewart and Hendrix, n. sp. right valve view of only specimen. Holotype, O.S.U. 18871, locality 2a. (p. 110)

13, 14—Bairdia pseudomagna Stewart and Hendrix, n. sp. *13*, Right valve view showing highly arched character of specimen; *14*, Left valve view of larger specimen. Both are casts of interior. Syntypes (2), O.S.U. 18868, locality 2a. (p. 110)

15, 16—Bythocypris lucasensis Stewart?, *15*, Right valve view of cast of interior; *16*, Dorsal view of another specimen. Plesiotypes (2), O.S.U. 18895, locality 4a. (p. 111)

17, 18—Thrallella mimica Stewart and Hendrix, n. g., n. sp. *17*, Right valve view of typical specimen, posterior pits are obscured by ammonium chloride; *18*, Interior view of left valve. Syntypes (2), O.S.U. 18877, locality 2a. (p. 111)

19—Thrallella phaseolina Stewart and Hendrix, n. sp. Right valve view showing ridge and pitted character of posterior end. Holotype, O.S.U. 18875, locality 2a. (p. 111)

20, 21—Thrallella susanola Stewart and Hendrix, n. sp. *20*, Right valve view, posterior pits obscured; *21*, Dorsal view showing characteristic posterior shoulder on each valve. Syntypes (2), O.S.U. 18876, locality 2a. (p. 112)

22, 23—Richterina symmetrica Stewart and Hendrix, n. sp. *22*, Specimen showing fine longitudinal concentric ridges. *23*, Smaller specimen, concentric ridges obscured by ammonium chloride. Syntypes (2), O.S.U. 18879, locality 2a. (p. 112)

24–26—Senescella marginaspinata Stewart and Hendrix, n. g., n. sp. *24*, Right valve view of holotype showing characteristic surface features; *25*, interior view of right valve; *26*, Dorsal view showing characteristic shoulder on each valve. Holotype and paratypes (2), O.S.U. 18880, locality 2a. (p. 113)

27–29—Senescella crassimarginata Stewart and Hendrix, n. sp. *27*, Left valve view showing irregular nodose character of surface; *28*, Right valve interior showing wide contact margin; *29*, Dorsal view showing anterodorsal spine on each valve. Syntypes (3), O.S.U. 18881, locality 2a. (p. 113)

30, 31—Senescella longaeva Stewart and Hendrix, n. sp. *30*, Interior right valve *31*, Exterior right valve showing well-developed surface spines. Syntypes (2), O.S.U. 18882, locality 2a. (p. 114)

32—Senescella longaeva var. *deflecta* Stewart and Hendrix, n. var. Right valve. Holotype, O.S.U. 18883, locality 2a. (p. 114)

number of marginal flanges and transverse ridges, and in possessing a large subcentral node with pit directly below it. However, the backward swing is decidedly more pronounced in this form than in either of the other species, thus making the outline different; the posterior end is more truncate in appearance, and the carina nearest the margin is notched instead of being smooth.

This species is named for Ralph J. Bernhagen, geologist for the Water Conservation Board in Ohio.

SYNTYPES (3): Ohio State University Geol. Mus., 18861, locality 2a.

Also occurs at localities 1a, 2b, and 3a.

AMPHISSITES CARMANI Stewart and Hendrix, n. sp.
Plate 11, figures 22–24

Shell of medium size, subrectangular to subrhomboidal in outline; greatest length in dorsal half, greatest height in posterior half, greatest thickness central; hinge straight, occupying entire dorsal margin; ventral margin slightly convex; posterior margin more broadly rounded than anterior, most extended in upper half; dorsal margin concave, rising toward both ends, a little higher posteriorly; anterior cardinal angle somewhat more acute than posterior.

Valves moderately convex, essentially equal; only single valves have been seen so overlap, if any, cannot be determined; hinge of left valve with distinct groove into which right valve fits, slight flangelike projection of shell at each cardinal angle.

Surface of both valves strongly punctate. Each valve with two smooth marginal carinae paralleling ventral margin, converging at ends, meeting at cardinal angles, separated from one another and from margin of shell by narrow punctate bands, the band between carinae being widest. In median dorsal portion of each valve is large elongate node surmounted by weak vertical ridge in larger, older specimens; small pit, formed by union of two or more punctae, may or may not be present directly below node. Two distinct vertical ridges present in anterior and posterior portions of each valve, the latter being longest, most strongly developed.

Dimensions of separate left valve: length, measured in dorsal half, 0.93 mm.; height, measured posteriorly, 0.52 mm.

In external view the valves are a little difficult to orient; the blunter end is interpreted as anterior, and the valve with grooved hinge is considered to be the left one.

This species does not seem to resemble closely any described Devonian species known to the authors. It does, however, resemble very closely the Mississippian species *Amphissites chappelensis* Roundy, 1926, from the Barnett shale of Texas but its outline is more rectangular, the central node is larger and more dorsal in position, and the posterior ridge is more acute.

This species is named for Professor J. E. Carman, Department of Geology, Ohio State University.

SYNTYPES (3): Ohio State University Geol. Mus. 18860, locality 2a.

Also occurs at localities 1a, 2b, 2c, 3a, and 6b.

AMPHISSITES SHAFFERI Stewart and Hendrix, n. sp.
Plate 11, figures 25–27

Carapace moderately convex, more or less bean-shaped in lateral view, with slight backward swing. Shell highest just anterior to postcardinal angle, longest midway between dorsal and ventral margins; thickest centrally. Hingement not definitely determined because no interiors have been available for study. Hinge shallowly sulcate, apparently extends throughout dorsal margin. Dorsal margin concave in side view, shell surface rising slightly above hinge; viewed dorsally central concavity appears as saddlelike depression. Ventral margin scarcely convex, merges evenly into ends, anterior somewhat prow-shaped, posterior with slight backward swing.

Valves apparently equal, meeting evenly along all margins with no sign of overlap.

Surface entirely reticulate. Two marginal carinae on each valve; outer one parallels ventral margin, converges on ends, ends about halfway to cardinal angles; inner carina crescentric, dies out at both ends about midway between ventral and dorsal margins. Node present on each valve directly below dorsal margin just anterior to center of shell. Small pit just below and slightly

posterior to node. Two ridges rather weakly developed, more or less vertical present in middle of both anterior and posterior halves of each valve, extending downward from dorsal margin, terminating just above upper carina. In some specimens posterior ridge curves noticeably backward. Each ridge terminates dorsally at highest place in each half of margin.

Dimensions of average specimen: length, measured midway between upper and lower margins 0.78 mm.; height, measured at termination of posterior vertical ridge, 0.49 mm.; thickness, measured through central nodes, 0.36 mm.

This form is represented by about half a dozen complete specimens. It can be separated readily from the associated species of *Amphissites* by its shape, its crescentric upper carina, and its less strongly developed vertical ridges. All three species have the kirkbyan pit poorly developed. There seems to be no other described Devonian species with which to compare this form. It does resemble somewhat the Mississippian species *A. centronotoides* Geis 1932, but that form has anterior and posterior nodes instead of ridges that are connected dorsally by a distinct ridge.

This species is named for Paul R. Shaffer, Department of Geology, Ohio Wesleyan University.

SYNTYPES (3): Ohio State University Geol. Mus. 18862, locality 2a.

Also occurs at localities 1a, 2b, 2c, 3a, and 5a.

Family GLYPTOPLEURIDAE Girty
Genus FRANKLINELLA Stewart and Hendrix, n. gen.

Carapace thick-valved, of coarse appearance, subovoid to subquadrate in outline; hinge straight, simple in structure, occupying entire dorsal margin; valves equal. Surface with several strong transverse costae, lower four converge posteriorly to form large backward pointing postventral spine, upper four converge anteriorly to form laterally-pointing anterodorsal spine. Submedian crescentric forward-curving sulcus extends downward from dorsal margin terminating at upper of three lowest costae.

This genus bears a striking resemblance to *Glyptopleura* in the development of its transverse costae. It differs, however, in having some of the costae converge at each end to form conspicuous spines, in having a median sulcus rather than a median pit, and in having apparently equal valves rather than the left being larger and overlapping the right.

GENOTYPE: *Franklinella novecosta*, n. sp.

FRANKLINELLA NOVECOSTA Stewart and Hendrix, n. sp.
Plate 11, figures 28, 29

Carapace large, subovoid in side view; maximum height practically at posterior end; thickness greatest approximately in central area; length greatest about midway between upper and lower margins; hinge straight, occupying entire dorsal margin, without any apparent groove or ridge on either valve; posterocardinal angle broadly rounded, anterocardinal angle acute; ventral margin convex, rising anteriorly, dorsal margin sloping posteriorly; posterior end with backward swing, margin concave just above postventral spine, convex, most extended in upper half; anterior margin more narrowly, evenly rounded.

Carapace somewhat compressed, apparently equivalved, although one specimen seems to have right valve overlapping left at posterior end possibly as result of left valve being accidentally flattened in posterior part.

Crescentric, submedian forward-curving sulcus extends downward from dorsal margin, terminates a little below median line of valve. Surface crossed transversely by at least eight heavy costae; uppermost present only on postdorsal portion of valve; next four joined anteriorly where they are produced into large laterally-pointing spine just behind anterodorsal margin; sixth costa from top present only on posterior portion of the valve, ending where it is crossed by seventh costa; four lowest costae oblique to other 6, joined and produced backward into large backward-pointing, postventral spine. Lowest costa parallels ventral margin, continues around anterior parallel to margin. Second lowest costa also continues around anterior end, truncates ends of next two costae above.

Dimensions of average specimen: length in upper half 0.122 mm.; height, slightly in

front of posterior margin, 0.87 mm.; thickness, measured centrally, 0.41 mm.

Several good specimens of this species have been found. It resembles the associated *F. septecosta*, but has two more costae and is shorter in relation to its height.

HOLOTYPE AND PARATYPE: Ohio State University Geol. Mus. 18863, locality 2a.

Also occurs at localities 2b, and 2c.

FRANKLINELLA NOVECOSTA OBESA Stewart and Hendrix, n. var.
Plate 12, figures 1, 2

This variety differs from the typical form only in usually being smaller and decidedly more convex. Some specimens are quite gibbous. A comparison of measurements in millimeters of several specimens of both types follows:

F. novecosta n. sp.

	Length	Height	Thickness
1.	1.30	0.92	0.46
2.	0.99	0.64	0.38
3.	1.22	0.87	0.44
4.	1.02	0.73	0.35

F. novecosta obesa n. var.

	Length	Height	Thickness
1.	1.02	0.73	0.44
2.	1.02	0.78	0.55
3.	1.10	0.73	0.61
4.	1.02	0.73	0.52

These measurements show that the ratio of length to height in the two forms is remarkably uniform, but the thickness is variable and this does not appear to be simply a matter of individual variation.

This is one of the most abundant forms collected and it is represented by many fine specimens.

SYNTYPES (2): Ohio State University Geol. Mus. 18864, locality 2a.

Also occurs at localities 2b, and 2c.

FRANKLINELLA SEPTECOSTA Stewart and Hendrix, n. sp.
Plate 12, figures, 3, 4

Carapace oblong, approaching shape of parallelogram with distinct backward swing; maximum height in posterior third; maximum thickness in middle of anterior half; maximum length in middle of upper half; hinge slightly concave, extending throughout dorsal margin; ventral margin convex; anterior margin more broadly, evenly rounded than posterior, most extended in lower half; posterior margin concave in lower part, convex and protuberant in upper half.

Carapace equivalved; hingement simple, formed by contact of dorsal margins of valves. Surface marked by 7 transverse costae, upper 4 produced forward into laterally pointing anterodorsal spine, lower three produced backward into large postventral spine. An incipient eighth costa suggested in some specimens. Crescentric forward-curving sulcus a little anterior to middle of each valve, extending from dorsal margin downward, cutting four upper costae, terminating at fifth.

Dimensions of more perfect specimen: length, measured centrally, 1.22 mm.; height, measured posteriorly, 0.78 mm.; thickness, measured through anterodorsal nodes, 0.38 mm.

This species is represented by only two single right valves. It may be distinguished from *F. novecosta* by its proportionately longer outline, more narrowly rounded and extended upper posterior margin, and by its seven well-developed costae instead of nine.

SYNTYPES (2): Ohio State University Geol. Mus. 18865, locality 2a.

Also occurs at localities 2b, and 2c.

Family ROPOLONELLIDAE Coryell and Malkin

Genus ROPOLONELLUS Van Pelt

ROPOLONELLUS? DUBIUS Stewart and Hendrix, n. sp.
Plate 12, figures 5, 6

Carapace small, subelliptical in outline; dorsal margin arched in posterior half where maximum height occurs; posterior end much higher than anterior; ventral margin straight to slightly convex, rising forward to narrowly rounder anterior; posterior much more broadly rounded than anterior, in side view concealed by the posterior flanges; carapace longest midway between upper and lower margins, thickest centrally.

Shell moderately convex, inequivalved, right valve larger, overlapping left, overlap greatest along ventral margin; hingement not observed. One specimen shows faint sulcus along dorsal margin.

Shell finely granulose. More or less frill-like posterior marginal flange present on each valve but not similarly placed. Flange on left valve in central and lower part, more strongly developed ventrally; two rather distinct nodes occur on one specimen about at dorsal and ventral terminations of flange. Flange on right valve extends around posterior margin, terminates abruptly just a little below dorsal margin. Neither flange parallels margin, both are turned laterally away from shell surface. Two small nodes occur in same positions on each valve, one in anteroventral region, other directly below dorsal margin in middle anterior half. Other nodes, faintly developed, seem to be scattered here and there over valves. Small spine present on anterior cardinal angle of right valve.

Measurements of largest specimen: length, measured midway between upper and lower margins, 0.73 mm.; height, measured posteriorly, 0.39 mm.; thickness, measured centrally, 0.29 mm.

Three well-preserved specimens of this interesting species were found but one was subsequently lost. Their family and generic affiliations are questionable. No definite pits, such as characterize most of the Thlipsuridae are present on either valve. This species does, however, resemble *R. papillatus* Van Pelt, 1933, in outline and similar posterior flanges but it has no anterior marginal ridge, and there are no papillae on the posterior ridge. Also the shape and position of the posterior flanges are different, and nodes are present on the body of the shell.

SYNTYPES (2): Ohio State University Geol. Mus. 18866, locality 2a.

Family BAIRDIIDAE Sars
Genus BAIRDIA McCoy
BAIRDIA BARTHOLOMEWENSIS Stewart and Hendrix, n. sp.
Plate 12, figures 7, 8

Carapace subelliptical in outline; maximum length slightly below midheight; maximum height in middle of anterior half; maximum thickness in central region; hinge straight, extending throughout length of dorsal margin; dorsal margin straight, not quite half the length of shell; ventral margin with slight concavity at midlength; both ventral and dorsal margins converge posteriorly; anterodorsal margin straight, curving abruptly into lower half of anterior margin; posterior margin strongly acuminate in central part, gently convex below acumination, concave above.

Valves moderately convex, left valve larger than right, overlapping all around except at anterior extremity and below posterior prolongation. Hingement formed by overlapping of left valve on right along dorsal margin. Surface granulose.

Dimensions: length measured centrally, 1.16 mm.; height measured in middle of anterior half 0.50 mm.; thickness measured centrally 0.39 mm.

One entire specimen and a cast of the interior of a smaller individual have been found. The most distinctive feature of this species is the acute prolongation of the posterior margin, by which it may be separated from the associated *B. delawarensis* n. sp., as well as by its more extensive overlap.

HOLOTYPE AND PARATYPE: Ohio State University Geol. Mus. 18870, locality 2a.

BAIRDIA DELAWARENSIS Stewart and Hendrix, n. sp.
Plate 12, figures 9, 10

Carapace subrhomboidal to semielliptical in lateral view; greatest height and thickness in central part; greatest length slightly below middle; dorsal margin straight, about half as long as shell; ventral margin slightly convex with faint concavity in central part; posterior margin acuminate, concave in upper half, prow-like in lower half; upper and lower thirds of anterior margin straight, central part narrowly rounded.

Valves moderately convex, unequal, left larger than right, overlapping on all margins except anterior; hinge formed by overlap.

Surface finely granulose, otherwise unornamented.

Dimensions of holotype: length, measured just below midheight, 1.02 mm.; height, measured centrally, 0.55 mm.; thickness, measured centrally, 0.41 mm.

One entire specimen and three interior casts have been collected that do not appear to be identical to any described Devonian species of *Bairdia*. They resemble *Bairdia leguminoides* Ulrich, 1891, from the Hamilton group of New York most closely, but the

overlap is not so pronounced as in that form, and the anterior is more rounded. Of the associated species they are closest to *B. bartholomewensis*, n. sp. but they are shorter, their dorsal and ventral margins are more nearly parallel, and their overlap is more restricted. They resemble somewhat *Bairdia peracuta* Warthin, 1930, from the Holdenville formation, Pennsylvanian, of Oklahoma, but that species has a more acuminate anterior.

HOLOTYPE AND PARATYPE: Ohio State University Geol. Mus. 18867, locality 2a.

Also occurs at locality 2b.

BAIRDIA LENTICULATA Stewart and Hendrix, n. sp.
Plate 12, figure 11

Carapace depressed convex, sublenticular in outline; greatest length in upper fourth of shell; height greatest in center, thickness greatest in middle of anterior half; dorsal margin arched, curving smoothly to ends where it merges into pronounced acuminations, posterior of which is the longest; both anterior and posterior margins strongly curved below acuminations, merge evenly into ventral margin, which is straight in central portion.

Shell inequivalved, left valve larger than right, strongly overlapping along entire upper portion of shell; hingement formed by overlap. Surface finely granulose.

Length measured through upper portion from point to point 0.84 mm.; height measured centrally 0.40 mm., thickness measured through middle of anterior half 0.23 mm.

This species is represented by a single distinctive specimen showing all features essential for specific designation. Although the shape is rather unusual for a *Bairdia* it probably belongs in that genus. There seems to be no described species closely similar to it. The amount of dorsal overlap is greater than in any species with which we are familiar, being about one-fifth the height of the shell. Also no other species seems to have both the anterior and posterior accuminations so close to the dorsal margin.

HOLOTYPE: Ohio State University Geol. Mus. 18869, locality 2a.

BAIRDIA PSEUDOMAGNA Stewart and Hendrix, n. sp.
Plate 12, figures 13, 14

Carapace of medium size, subtriangular in side view; greatest length central or slightly lower; greatest height a little posterior to midlength, equal to about two-thirds the length; greatest thickness central; character of hinge uncertain; dorsal margin strongly arcuate in central part, sloping abruptly to ends; posterior margin acuminate in central part, concave above, convex below; anterior margin narrowly rounded; ventral margin strongly convex.

Dimensions of two specimens: length, 1.12 mm. and 0.93 mm., height, 0.73 mm. and 0.70 mm., thickness, 0.49 mm. and 0.35 mm.

Although this species is represented by only two casts of the interior the outline is so different from any other Devonian species that we feel justified in distinguishing them as a new species. So far as we know there is no other form so highly arched, and in this respect it resembles very closely the two Cretaceous species *B. subdeltoidea* var. *rotunda* Alexander and *B. magna* Alexander. *Bairdia grahamensis* Harlton, a Mississippian species is likewise similar, but the anterior end is more acuminate.

SYNTYPES (2): Ohio State University Geol. Mus. 18868, locality 2a.

BAIRDIA UNICA Stewart and Hendrix, n. sp.
Plate 12, figure 12

Carapace of medium size, subrhomboidal in outline; greatest length midway between upper and lower margins; greatest height and thickness central; hinge curved, apparently occupying entire dorsal margin, and possibly the upper part of the posterior; dorsal margin slightly arched, short; ventral margin slightly concave at midlength; posterior margin triangular in outline, upper half straight, the lower half gently curved; anterior margin broadly, evenly rounded.

Shell inequivalved, left valve larger, overlapping right on all but extreme posterior margin; overlap greatest in center of ventral margin.

Surface finely granulose.

Length, measured at midheight 0.90 mm.; height measured centrally 0.52 mm.; thickness, measured centrally 0.41 mm.

One specimen only has been found, but it seems to possess all characters essential for recognition. It differs from associated *B. delawarensis*, n. sp., by its more uniformly triangular posterior end, greater ventral overlap, and greater gibbosity.

HOLOTYPE: Ohio State University Geol. Mus. 18871, locality 2a.

Genus BYTHOCYPRIS Brady
BYTHOCYPRIS LUCASENSIS Stewart (?)
Plate 12, figures 15, 16

Bythocypris lucasensis Stewart 1936, Jour. Paleontology, vol. 10, no. 8, p. 755, pl. 101, fig. 17. Silica shale, Lucas County, Ohio.

The two specimens that have been collected from the Olentangy shale are identified with some question. They are considerably smaller and their shape is slightly different from typical specimens. Their greatest height is not at mid-length, but slightly posterior. Both specimens are internal casts.

PLESIOTYPES (2): Ohio State University Geol. Mus. 18895, locality 4a.

Family CYTHERELLIDAE Sars
Genus THRALLELLA Stewart and Hendrix, n. gen.

Carapace small; reniform to subreniform in outline; dorsal margin broadly arched to arcuate; ventral margin straight or slightly concave at midlength; ends almost equally rounded in some specimens, in others posterior end more broadly rounded. Hinge not definitely known, left valve probably with a slight groove into which right valve fits; valves subequal, left valve somewhat larger, more or less overlapping right.

Backward-curving, crescentric ridge or flange-like shoulder present in posterior portion of each valve. Within crescent several shallow pits occur in roughly circular area; posterior row regularly arranged along interior edge of crescent. Remaining surface granulose.

GENOTYPE: *Thrallella phaseolina* Stewart and Hendrix

THRALLELLA MIMICA Stewart and Hendrix, n. sp.
Plate 12, figures 17, 18

Carapace small, subreniform in outline; foreshortened, gibbous; greatest height slightly behind center; greatest thickness in central area; dorsal margin strongly arched, arcuate, with long gentle anterior slope; ventral margin straight to slightly concave; posterior margin broadly, evenly rounded; anterior margin more narrowly rounded.

Shell strongly convex, valves somewhat unequal, left slightly larger, overlapping right uniformly except for lesser overlap anteriorly. Hingement obscure, but slight groove appears to be present in post-dorsal region of left valve for reception of edge of right.

Short crescentric ridge, curving posteriorly, present in posterior portion of each valve. Just anterior to ridge 14 more or less well-defined pits occur in roughly triangular area, six most prominent pits arranged in row along inner edge of ridge. Remaining surface minutely pitted.

Length of a typical specimen measured midway between dorsal and ventral margins 0.46 mm.; height, measured postcentral, 0.29 mm.; thickness, measured centrally 0.26 mm.

This species is represented by three complete specimens and a single valve. The posterior ridge is shorter than in associated *T. susanola* n. sp. and the general appearance is more squatty. From *T. phaseolina*, n. sp. it differs in these same respects, and in addition the crescentric ridge is less shoulder-like.

SYNTYPES (2): Ohio State University Geol. Mus. 18877, locality 2a.

Also occurs at locality 1a.

THRALLELLA PHASEOLINA Stewart and Hendrix, n. sp.
Plate 12, figure 19

Carapace small, subreniform in lateral view; shell highest slightly posterior to center; thickest in posterior half, longest midway between upper and lower margins; hinge line short, straight, apparently postdorsal in position; dorsal margin broadly convex; ventral margin slightly concave centrally; posterior margin broadly rounded,

slightly projecting centrally; anterior margin more narrowly rounded.

Valves equally convex, left somewhat larger, overlapping right on all but dorsal margin, ventral overlap greatest; hinge structure not observed. Near posterior extremity of each valve crescentic ridge stands out like flange from shell surface, curves posteriorly; surface becomes distinctly concave between ridge and posterior margin. Within area of the crescent and extending about one-fourth of distance forward are from 16 to 18 shallow but distinct pits in more or less circular or triangular area. One row uniformly follows contour of shoulder. Remaining surface minutely pitted.

Length midway between dorsal and ventral margins 0.64 mm.; height midway between ends 0.32 mm.; thickness in middle of posterior half 0.23 mm.

This species is represented by one complete specimen. It is larger than the two associated species of *Thrallella*, and the posterior elevation is more shoulder-like than ridge-like. It may be distinguished from *T. **mimica***, n. sp. by the more nearly equal height of the ends and from *T. **susanola*** n. sp. by the shorter extension of the shoulder anteriorly along the dorsal margin. It may be separated from *T. **arcuata*** Turner by the shape which is distinctly bean-like rather than more or less triangular in side view.

HOLOTYPE: Ohio State University Geol. Mus. 18875, locality 2a.

THRALLELLA SUSANOLA Steward and Hendrix, n. sp.
Plate 12, figures 20, 21

Carapace small, subreniform in lateral view; greatest height slightly postcentral; greatest thickness central; greatest length midway between upper and lower margins; character of hinge not discernible; dorsal margin broadly arcuate; ventral margin with slight concavity; posterior margin somewhat more broadly rounded than anterior, with long gentle dorsal slope; slight angularity evident at anterodorsal extremity.

Valves deeply, equally convex, becoming considerably compressed anteriorly; left valve scarcely larger than right, overlapping slightly on ventral margin. Crescentric ridge parallels posterior margin, converging along dorsal margin, extending about one-fourth distance from anterior end of shell; at other end ridge ends abruptly in postventral area; surface slightly concave between ridge and posterior margin; about twelve uniformly spaced pits occur within crescent, one row following inner border of ridge. Remainder of surface appears minutely pitted.

Length of a typical specimen measured midway between dorsal and ventral margins 0.46 mm.; height measured a little postcentrally 0.23 mm.; thickness measured centrally 0.20 mm.

Four specimens, three complete internal casts and one separate valve have been assigned to this species. This species is smaller than *T. **phaseolina***, n. sp. and the pits are fewer in number and less definite; it is more slender than *T. **mimica*** n. sp. and the posterior ridge is longer and extends farther anteriorly along the dorsal margin.

SYNTYPES (2): Ohio State University Geol. Mus. 18876, locality 2a.

Family ENTOMIDAE Jones
Genus RICHTERINA Gürich
RICHTERINA SYMMETRICA Stewart and Hendrix, n. sp.
Plate 12, figures 22, 23

Carapace oval in outline; greatest height at midlength, greatest thickness central; hinge line curved, apparently occupying middle of dorsal margin; ventral and dorsal margins equally, evenly convex; ends broadly, equally rounded. Its perfect symmetry makes orientation of this species uncertain.

Shell equivalved; hingement not observed.

Surface covered with fine, longitudinally concentric ridges.

Length of average specimen: 0.87 mm.; height 0.55 mm.; thickness 0.43 mm.

The reference of this species to *Richterina* is fairly certain. This is interesting because the genus has not been reported previously from American Devonian strata. Elsewhere it seems to be restricted almost exclusively to the Upper Devonian. This species resembles closely *R. **costata*** Richter, but it has more bluntly rounded ends in dorsal view, and the ridges are concentric instead of more or less inosculating.

SYNTYPES (2): Ohio State University Geol. Mus. 18879, locality 2a. Also occurs at locality 5b.

Family BARYCHILINIDAE Ulrich
Genus SENESCELLA Stewart and Hendrix, n. gen.

Medium-sized, thick-shelled ostracodes, having old and wrinkled appearance; subrhomboidal to elliptical in outline; right valve larger, strongly overlapping left; with thickened margin; hingement formed by straight or curving groove along dorsal margin of right valve into which edge of left valve fits; surface strongly to moderately convex, flattening appreciably towards ends, as best seen in dorsal or ventral view. Anteromarginal spines may or may not be present. Entire surface finely pitted.

This genus is placed only provisionally in the family *Barychilinidae* because it does not appear to have very close affinities with any of the genera at present referred to that family. It probably resembles *Elesmaria* Tolmachoff most closely in its greatly thickened valves and in having its right valve larger, but species of that genus do not have spines and other surface features possessed by the following species.

GENOTYPE: *Senescella marginaspinata* Stewart and Hendrix.

SENESCELLA CRASSIMARGINATA Stewart and Hendrix, n. sp.
Plate 12, figures 27–29

Shell of medium size, very thick, elliptical to ovoid in outline; highest in middle of posterior half; commonly thickest in middle of anterior half; longest slightly below middle; hinge slightly curved, occupying entire dorsal margin; posterior margin arched, convexity greatest in middle of posterior half; ventral margin straight or slightly concave at midlength; posterior margin broadly rounded except in upper third where it is considerably flattened giving truncate appearance to that part of shell; anterior margin more narrowly rounded.

Shell very inequivalved, right valve larger, overlapping left all around, overlap greatest on upper and lower margins; hingement formed by shallow groove along dorsal margin of right valve into which edge of smaller left valve fits.

Convexity of valves moderate; surface with medium-sized reticulations in some specimens, very fine reticulations in others. Margin of right valve very greatly thickened all around, thickening greatest around posterior margin; central dorsal portion of valve usually slightly wrinkled, without definite ridges; small lateral spine occurs slightly anterior to center of valve, about one-fifth of distance down from dorsal margin. In some specimens additional short spines or nodes distributed over the surface without definite arrangement, projecting at various angles. Left valve with thickened posterior margin developing into definite ridge in upper portion bearing blunt spine in some specimens; shoulder may be present just below dorsal margin in anterocentral portion; small short spine projects laterally from anterior end of shoulder, present even if shoulder is lacking; this spine occupies position similar to that on right valve. Anterior margin of valve also thickened, deflected laterally; one or two low nodes present in some specimens. Surface slightly wrinkled in central portion, shallow sulcus parallels ventral margin in some specimens.

This species may be distinguished from *Senescella marginaspinata*, n. sp. by its slightly more senescent appearance, its anterodorsal laterally pointing spines, and the absence of anteroventral marginal spine.

SYNTYPES (3): Ohio State University Geol. Surv. 18881, locality 2a. Also occurs at localities 1a, 2b, and 2c.

SENESCELLA MARGINASPINATA Stewart and Hendrix, n. sp.
Plate 12, figures 24–26

Shell very thick, some specimens gibbous; subrhomboidal to ovoid in side view; greatest height in middle of posterior half; greatest thickness in middle of anterior half; hinge curved, extending along anterior and central portions of dorsal margin; dorsal margin strongly arcuate; ventral margin straight to slightly concave; posterior margin broadly rounded, in some specimens with truncate appearance in upper half; anterior margin more narrowly rounded, with distinct forward extension in upper half.

Valves very unequal, right larger, overlapping left all around; overlap greatest along dorsal and ventral margins, least in upper half of posterior margin where valves have mashed or flattened appearance; hingement formed by smaller left valve fitting

into distinct groove in anterior and central portions of dorsal margin of right valve. Entire margin of right valve greatly thickened. Surface very finely punctate.

Two blunt marginal spines project forward from margin of right valve. Larger spine located at anteroventral angle, appears as forward extension of ventral margin; in several specimens this spine broken or worn down. Smaller spine located on anterodorsal angle; in some specimens developed only as small node or slight swelling on margin, in others projecting considerably forward. Posterior margin of left valve greatly thickened, produced into flange-like ridge which dies out rapidly dorsally and ventrally; short curving shoulder in the anterodorsal portion of the valve in line with dorsal termination of ridge, usually topped by slight irregular ridge; shoulder usually quite high, drops abruptly to dorsal margin which is concealed by overlap of right valve.

Small additional spines scattered irregularly on forward portions of some right valves.

Shallow sulcus present on ventral portion of right valve just posterior of anteroventral spine, formed by bulging of ventral portion of valve; apparent only in ventral view.

Length of average specimen, measured at midheight 0.78 mm.; height, measured through middle of posterior half 0.55 mm.; thickness, measured through middle of anterior half 0.38 mm.

This species resembles *S. crassimarginata*, n. sp. very closely, having the same type of surface ornamentation, thickened margin of right valve, and general outline. The main differences are: presence of an anteroventral marginal spine in *S. marginaspinata*, absence of anterodorsal laterally pointing spines, and the slightly less senescent appearance.

HOLOTYPE AND PARATYPES (2): Ohio State University Geol. Mus. 18880, locality 2a. Also occurs at localities 1a, 2b, and 2c.

SENESCELLA LONGAEVA Stewart and Hendrix, n. sp.
Plate 12, figures 30, 31

Shell of medium size, rather thick, subrhomboidal in outline, with backward swing; greatest height in middle of posterior half; greatest length midway between upper and lower margins; greatest thickness in middle of anterior half; hinge straight, occupying entire dorsal margin; ventral margin somewhat thickened, rising forward, slight concavity at midlength; posterior margin broadly rounded, slightly truncated in upper portion; anterior margin narrowly rounded.

Relative sizes of valves not observed but right is undoubtedly larger, because groove occurs along dorsal margin for reception of other valve.

Surface finely granulose. Large, laterally projecting spine present in upper dorsal half slightly anterior to center; large, flat, obliquely directed marginal spine present on posterior margin just above middle; small marginal spine or node occurs at anterodorsal angle.

Length, measured centrally 0.76 mm.; height, measured posteriorly 0.46 mm.; thickness, measured anteriorly 0.20 mm.

This species is represented by two well-preserved right valves. The marginal thickening is not nearly so prominent as in the associated *S. crassimarginata*, n. sp. and *S. marginaspinata*, n. sp., nor does the shell have such a senescent appearance; also this species differs from the former in bearing a spine in the middle of the posterior margin; and from the latter in the absence of the anteroventral marginal spine.

SYNTYPES (2): Ohio State University Geol. Mus. 18882, locality 2a. Also occurs at locality 2b.

SENESCELLA LONGAEVA DEFLECTA Stewart and Hendrix, n. var.
Plate 12, figure 32

A single well-preserved right valve differs sufficiently from the typical form to justify separation as a variety. It differs by the ventral, instead of dorsal, position of the main body spine, and by the absence of the mid-posterior marginal spine and anterodorsal node. Also, the upper part of the posterior margin is reflected laterally.

HOLOTYPE: Ohio State University Geol. Mus. 18883, locality 2a.

REFERENCES

ALEXANDER, C. I., 1927, The stratigraphic range of the Cretaceous Ostracoda *Bairdia subdeltoidea* and its allies: Jour. Paleontology, vol. 1, no. 1, pp. 29–33.

BAKER, ROGER C., 1942, The age and fossils of the Olentangy shale of central Ohio: Am. Jour. Sci., vol. 240, pp. 137–143.

BASSLER, R. S. and KELLETT, BETTY, 1934, Bibliographic index of Paleozoic Ostracoda: Geol. Soc. America, Spec. Papers No. 1.

——, 1941, Ostracoda from the Devonian (Onondaga) chert of west Tennesse: Washington Acad. Sci. Jour., vol. 31, no. 1, pp. 21–27.

COOPER, G. ARTHUR, et al., 1942, Correlation of the Devonian sedimentary formations of North America: Geol. Soc. America Bull., vol. 53, pp. 1729–1794.

CORYELL, H. N., 1928, Some new Pennsylvanian Ostracoda: Jour. Paleontology, vol. 2, no. 2, pp. 87–94.

—— and BOOTH, R. T., 1933, Pennsylvanian Ostracoda, a continuation of the study of the Ostracoda fauna from the Wayland shale, Graham, Texas: Am. Midland Naturalist, vol. 14, no. 2, pp. 258–280.

GEIS, H. L., 1932, Some ostracodes from the Salem limestone, Mississippian, of Indiana: Jour. Paleontology, vol. 2, no. 2, pp. 149–188.

GRAHAU, AMADEUS, 1915, The Olentangy shale of central Ohio and its stratigraphic significance: Geol. Soc. America Bull., vol. 26, p. 112.

——, 1927, Age and stratigraphic relations of the Olentangy shale of central Ohio, with remarks on the Prout limestone and so-called Olentangy shale of northern Ohio: Jour. Geology, vol. 25, pp. 337–343.

JONES, T. R., 1890, On some Devonian and Silurian Ostracoda from North America, France, and the Bosphorus: Geol. Soc. London, Quart. Jour., vol. 46, pp. 534–557.

——, 1890, On some Paleozoic Ostracoda from North America, Russia, Wales, and Ireland: Geol. Soc. London, Quart. Jour., vol. 46, pp. 1–32.

LAMBORN, R. E., 1927, The Olentangy shale in southern Ohio: Jour. Geology, vol. 35, pp. 721–722.

ROUNDY, P. V., 1926, Mississippian formations of Sansaba County, Texas. Part II, The micro-fauna: U. S. Geol. Survey Prof. Paper 146, pp. 5–24.

——, 1928, Description of ostracodes: Jour. Paleontology, vol. 1, no. 1, pp. 11–12.

STAUFFER, C. R., 1909, The middle Devonian of Ohio: Ohio Geol. Survey, ser. 4, Bull. 10.

——, 1916, The relationships of the Olentangy shale and associated Devonian deposits of northern Ohio: Jour. Geol., vol. 24, pp. 476–487.

——, 1938, The fauna of the typical Olentangy shale: Jour. Geology, vol. 46, no. 8, pp. 1075–1078.

SWARTZ, FRANK M., 1933, Dimorphism and orientation in ostracodes of the family Kloedenellidae from the Silurian of Pennsylvania: Jour. Paleontology, vol. 7, no. 3, pp. 231–260.

——, 1936, Revision of the Primitiidae and Beyrichiidae, with new Ostracoda from the lower Devonian of Pennsylvania: Jour. Paleontology, vol. 10, no. 7, pp. 541–586.

—— and SWAIN, FREDERICK M., 1942, Ostracodes of the middle Devonian Onondago beds of central Pennsylvania: Geol. Soc. America Bull., vol. 53, pp. 381–451.

WESTGATE, LEWIS G., 1926, Geology of Delaware County: Ohio Geol. Survey, ser. 4, Bull. 30.

WINCHELL, N. H., 1874, The geology of Delaware County: Ohio Geol. Survey, vol. 2, pt. 1, pp. 272–313.

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JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 2, PP. 116–125, PLS. 13–16, 1 TEXT FIG., MARCH 1945

BICORBULA, A NEW PERMIAN BRYOZOAN, PROBABLY A BRYOZOAN-ALGAL CONSORTIUM

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ABSTRACT.—*Bicorbula arizonica*, from the Kaibab formation, Middle Permian of Arizona is a new genus and species, related to *Polypora*. It consists of a cylindrical branching basket composed of two parallel meshworks. The outer meshwork bears zooecial apertures on the outside. The inner basket is without zooecia and probably was formed by symbiotic red alga.

INTRODUCTION

SPECIMENS of a new Permian *Polypora*-like basket with two layers of meshwork were collected by Condra in 1936 and 1940. These fossils were completely enclosed in solid silicified rock and they were originally observed only as cross-sections on broken surfaces that appeared as peculiar double-rings or double-loops, not unlike crosssections of the Permian alga *Mizzia* (Johnson, 1942, pl. 12), but 5 to 10 times as large. Little concerning their nature could be determined until specimens were prepared and studied microscopically.

In a conference by the senior author with Dr. R. S. Bassler and Dr. R. C. Moore in 1937 the nature and possible taxonomic treatment of the double-basket organism were discussed, and a conclusion was reached that it should be described as a new genus and new species. The possibility that the inner, nonporiferous basket had been formed by an alga was expressed by Bassler, and the same conclusion was independently reached by Elias after comparative studies of fossil and living algae and bryozoa. *Bicorbula*, therefore, may be another case of an intimate symbiotic growth-form or consortium of a fenestrate bryozoan and a phytomorph, probably an alga. The paleozoic genus *Archimedes* has been already interpreted as such a symbiotic consortium (Condra and Elias, 1942).

OCCURRENCE

The wide occurrence, both vertically and horizontally, of this peculiar fossil at Kaibab Plateau proves that the double-basket feature is not a freak or accidental occurrence but the fixed habit of a complex organism which became stabilized and grew abundantly during Kaibab time.

Bicorbula arizonica, n. sp., was collected by Condra from the cherty fossiliferous zone in the middle of the Kaibab limestone, exposed along the upper part of U. S. highway No. 89 east of Jacobs Lake in northern Arizona and near Bright Angel trail west of Grand Canyon, about 55 miles north-northwest of Williams, Arizona.

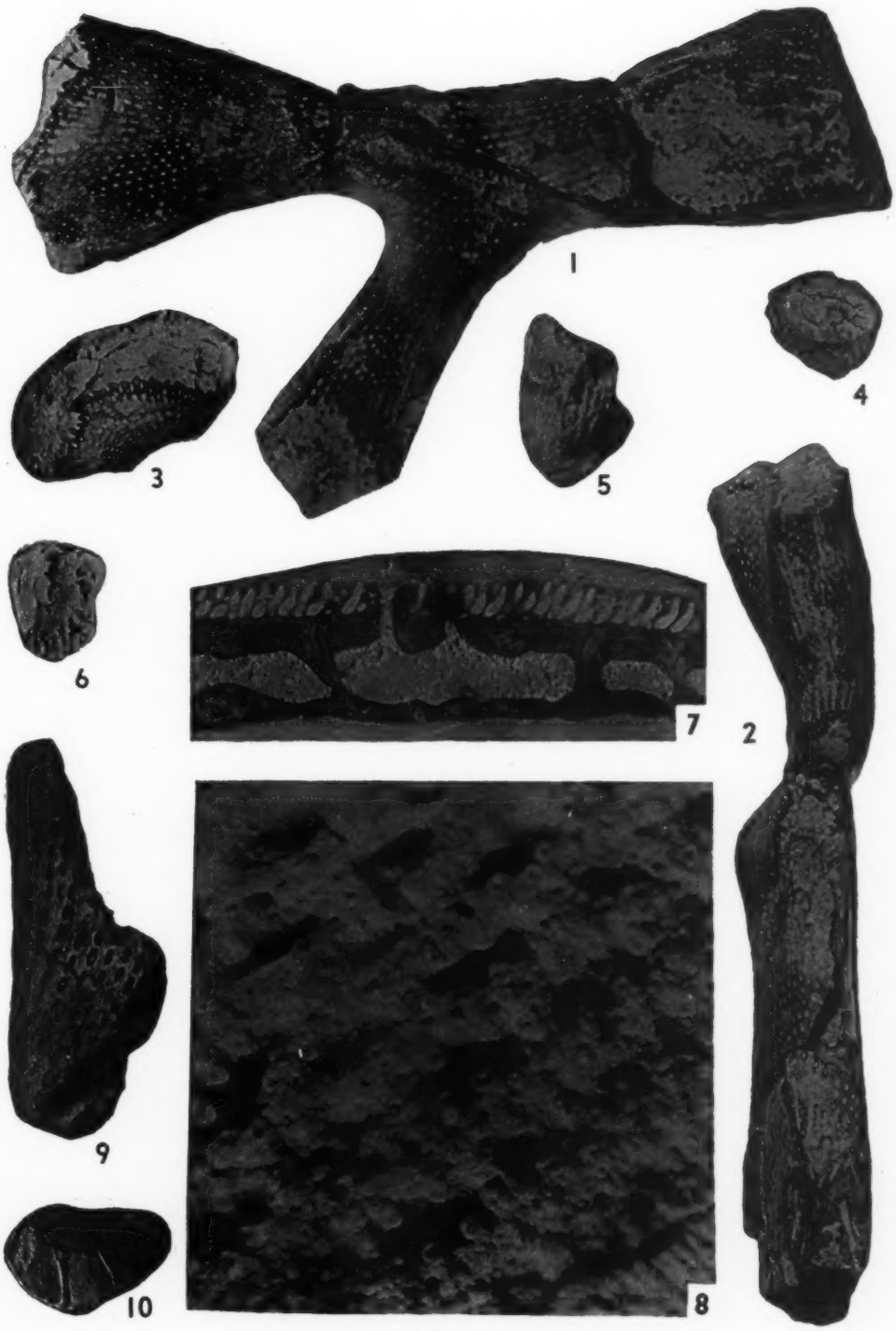
A complete list of the associated fossils in our collection is as follows:

Coelenterata
  cf. *Lindstroemia permiana* Girty
Porifera
  Sponge (?) of uncertain affinity

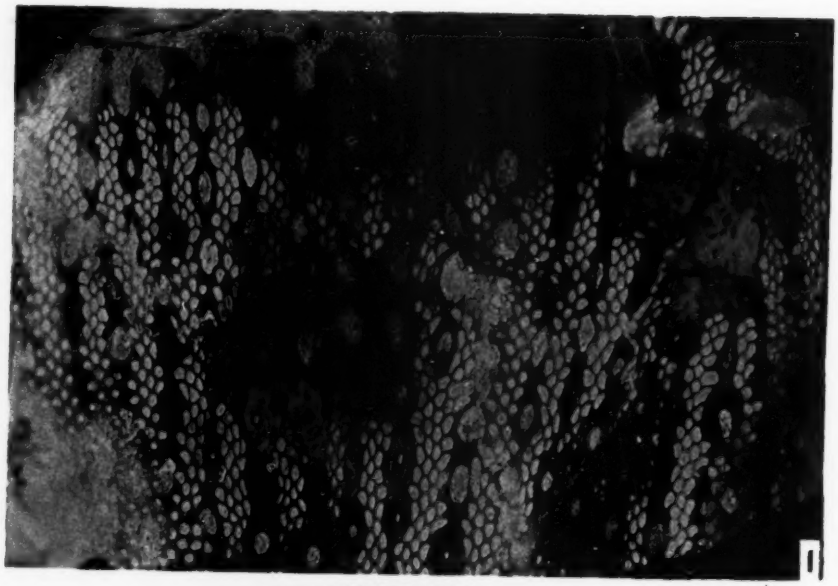
EXPLANATION OF PLATE 13

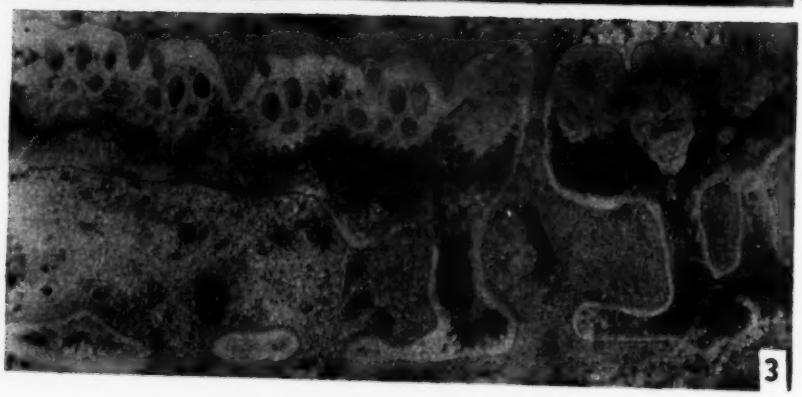
FIGS. *1–8*—*Bicorbula arizonica* Condra and Elias, n. g., n. sp. Kaibab formation, Grand Canyon, Arizona, *1–3*, Holotype Nebraska Geol. Survey no. 264; front (*1*), side (*2*), top (*3*) views; ×2. *4–6*, Paratype N.G.S. no. 266; top (*4*), side (*5*), bottom (*6*) views of a fragment near initial part of colony; ×2. *7*, Paratype N.G.S. no. 270; polished section along basket at about middle of its branch; ×20. *8*, Paratype N.G.S. no. 265; obverse surface of zooecial (outer) basket, showing round apertures and inconspicuous, indistinct nodes; ×20. (p. 118)

9–10—*Polypora* cf. *P. cestriensis* Ulrich. Wetumka formation, upper Des Moines, about 10 miles east of Ada, Oklahoma. Nebraska Geol. Survey no. 272. Cylindrical zoarium with tendency toward bifurcation distad, and two cross-connecting brace-like columns of phytomorphic tissue; side (*9*), bottom (*10*) views; ×2.



Condra and Elias—Bicorbula





Condra and Elias—Bicorbula

Echinoidea (spines)
Archaeocidaris cf. *A. cratis* White
Archaeocidaris n. sp.
Bryozoa
Fistulipora sp.
Meekopora cf. *M. prosseri* Ulrich
Stenopora cf. *S. granulosa* Girty
Stenopora cf. *S. heteropora* Condra
Stenopora aff. *S. carbonaria* (Worthen)
Bicorbula arizonica Condra and Elias, n. sp.
Septopora n. sp.
Rhombopora n. sp.
Insertae sedis
Bascomella subsphaerica Condra and Elias (1944, pl. 12, fig. 1; a questionable ctenostomatous bryozoan in the shell of *Rhipidomella hessensis*)
Brachiopoda
Rhipidomella carbonaria (Swallow)
Rhipidomella hessensis King
Derbya nasuta Girty
Chonetes kaibabensis McKee
Buxtonia victoriensis King
Waagenoconcha montpellierensis Girty
Avonia subhorridus newberryi McKee
Dictyoclostus paraindicus McKee
Dictyoclostus occidentalis (Newberry)
Dictyoclostus ivesi (Newberry)
Dictyoclostus bassi McKee
Marginifera sp.
Pugnoides shumardianus (Girty)
Pugnoides n. sp. (?)
Squamularia guadalupensis (Shumard)
Punctospirifer welleri (Girty)
Composita arizonica McKee

This fauna belongs to the no. 2 zone of the Kaibab section of Darton (1925, p. 99), and to the open-sea facies of the middle member (designated facies 1, member B by McKee, 1938, p. 45–46; or member B of Stoyanov, 1936, p. 527–529) of the restricted Kaibab formation. Almost all of the brachiopods listed by McKee are represented in our collection, which also contains a few other species, such as *Buxtonia victoriensis*. In the Bright Angel section given by McKee (1938, fig. 12 opp. p. 35), the fauna with *Bicorbula arizonica* occurs in zone X′.

According to correlation by McKee (1938 p. 171) the Kaibab limestone corresponds to the upper part of the Leonard series in the Glass Mountains of Texas.

PRESERVATION

Rock of the *Bicorbula*-bearing zone is completely silicified and varies from porous, comparatively soft and easily crushed material to solid or nearly solid very hard chert so intermixed that some silicified fossils occur partly in porous and partly in solid matrix.

Many of the brachiopods are weathered out or can be liberated from the matrix by breaking the rock. Bryozoa, however, generally are completely enclosed in the matrix and appear as cross sections on broken surfaces. The peculiar double-basket of *Bicorbula* was originally discovered in such sections, where it formed double concentric rings or ellipses instead of single rings or ellipses, as in sections of ordinary cylindrical zoaria of *Polypora*. Only one specimen was found in the large collection whose outer poriferous surface had been exposed by weathering (pl. 15, fig. 1). Some sections on broken surfaces, however, suggested the possible presence of more nearly complete baskets. These could be studied by (1) preparation of a series of successive parallel sections or (2) liberation of the basket from the matrix. Advantages of the latter method seemed obvious, providing the preparation could be satisfactorily accomplished. The following method proved reasonably fast and safe, and resulted in the liberation of a fairly good and only slightly damaged specimen (pl. 13, figs. 1–3).

METHOD OF PREPARATION

The specimen selected for preparation was broken in order to determine the course of the basket in the rock. It was placed on a wooden block and excessive rock was chipped off with an ordinary geologic ham-

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EXPLANATION OF PLATE 14

FIGS. *1–3*—*Bicorbula arizonica* Condra and Elias, n. g., n. sp., Kaibab formation, Grand Canyon, Arizona. *1*, Paratype, Nebraska Geol. Survey no. 267; polished tangential section cutting different levels of zooecial (outer) basket; ×10. *2*, Paratype N.G.S. no. 268; view of transverse break, showing parts of two parallel baskets connected by transverse uprights; on left two uprights fuse when approaching inner basket; ×20. *3*, Holotype N.G.S. no. 264; polished transverse section showing grooved reverse of zooecial branches sharply differentiated from encrusting phytomorphic tissue; ×20; slightly retouched.

mer. When chipping advanced dangerously close to the edges of the basket (visible in cross-sections) further trimming was done with a cold chisel. At some places the contact between the basket and matrix proved to be a plane of weakness and cracks developed along it. At others, however, cracks formed across the basket and chipping had to be stopped somewhat short of the contact. Remaining portions of adhering rock were ground away against the beveled edge of an ordinary rectangular abrasive stone and by the use of various revolving tools in a small electric hand grinder. Finally, the exposed surfaces of the basket were polished and the broken parts were cemented together (pl. 1, fig. 1).

The prepared specimen shows branching of the cylindrical basket somewhat similar to the branching of ramose bryozoa, not previously known in the fenestrate Paleozoic Cryptostomata.

METHODS OF STUDY

In early investigations of fossil bryozoa the complete or nearly complete zoaria were generally illustrated and described but the study of details was commonly neglected. With advance in the technique of preparation thin sections received more attention. Because most fossil zoaria are represented by abundant fragments these became a favorite subject of microscopic research and many new species were established on such fragments, differentiated on the basis of the spacing of the zooecia, branches and dissepiments, and on other microscopic features, while the nature of complete zoaria remained unknown. Study of complete or nearly complete zoaria in our collections and a few published illustrations of large zoarial fragments clearly shows that the spacing of these elements is not constant in at least some species of fenestrate bryozoa (for similar observations on Carboniferous Fenestellidae see Shrubsole, 1881), and supposedly different species established on fragments actually may be parts of a single species. Also the growth-form of a zoarium and the initial stages of its growth undoubtedly have an important bearing on the natural classification of Bryozoa. Consequently we devoted considerable effort in preparing as complete a basket of *Bicorbula* as possible.

BICORBULA Condra and Elias, n. gen.

A cylindrical fenestrate double-basket; meshwork of outer basket like *Polypora*, with more than two rows of zooecia in branches, no zooecia on dissepiments; all zooecia facing outward. Inner basket nonporiferous, irregular, connected to outer meshwork by numerous short uprights tending toward regular arrangement in transverse and longitudinal rows.

GENOTYPE: *Bicorbula arizonica* Condra and Elias, n. sp.

BICORBULA ARIZONICA Condra and Elias, n. sp.

Plate 13, figures 1–8; plate 14, figures 1–3; plate 15, figures 1–7; plate 16, figures 1, 2

A complex, closed, cylindrical, bifurcating double-basket with typical *Polypora* meshwork. Branches of outer meshwork are more or less straight, not undulating, connected by regularly spaced transverse dissepiments without zooecia. Each branch with more than two rows of zooecia, all on outer or obverse side of cylinder.

Youthful stages of basket unknown. (Youngest stage observed, pl. 13, fig. 6.) General shape varies from regular cylinder with nearly circular cross-section (pl. 15, fig. 4) through more and more compressed forms (pl. 13, figs. 4, 6) to flattened shape, with two wide, more or less parallel sides (pl. 15, fig. 2, 3) one or both of which may be concave. Just below bifurcation of basket (pl. 13, fig. 3) the sides meet and form looped cross-section like an 8. Each zoarial branch above bifurcation is elliptical with long axis in plane of bifurcation. Occasional bifurcations of branches of zooecial meshwork generally preceded by rapid lateral expansions of branches. Branches fairly constant in width and spacing, commonly straight, but may undulate laterally in zig-zag fashion for distance of a few fenestrules (pl. 14, fig. 1). All branches lie within cylindrical surface of meshwork spreading laterally in fan-like fashion. Where neighboring series of spreading branches meet one is truncated by the other.

Meshwork of outer basket like *Polypora* in all respects, nearest to typical *Polypora elliptica*. Branches with zooecia in two to five rows, generally three, but commonly fourth row is added for distance of several

fenestrules, and fifth may be present for about one fenestrule just below a bifurcation. Above bifurcation narrower branches bear only two rows which may continue for several fenestrules, but three occur in slightly wider branches. Sculpture rarely observable but in one area zooecial apertures are evidently round and prominent with scattered small intervening nodes (pl. 13, fig. 8). It is not known if these nodes are arranged in fours around each aperture of the central row as in restricted *Polypora elliptica* (Elias, 1937, p. 330).

Dissepiments short and wide, without zooecial apertures. Where branches undulate dissepiments tend to become obsolete and marginal zooecia of two laterally connected branches may be separated only by a common zooecial wall (pl. 14, fig. 1, left upper part).

Zooecial chambers of variable shape in tangential sections, elongated longitudinally with tendency to hexagonal or rhombic outline with rounded corners. Outlines become rounded and contracted at vestibulum (pl. 14, fig. 1, left lower corner). In longitudinal sections (pl. 13, fig. 7) chambers widen posteriorly; starting parallel to axis of branch they rise rapidly to diagonal and then to vertical positions, perpendicular to axis and ending in bottle-necked vestibulae. No hemisepta observed.

Measurements are as follows: Number of branches, 13 to 16 in 10 mm.; number of fenestrules, 10 to 12 in 10 mm.; number of zooecia in longitudinal row, 19 to 20 in 5 mm. Width of branches from 0.15 to 0.3 mm., as measured between outer edges of marginal zooecia, not including encrusting tissue which may add to width and tends to close fenestrules. Width of narrow elliptical fenestrules, when not reduced by encrusting tissue from about 0.06 to 0.18 mm.; length normally 0.2 to 0.3 mm.

Reverse of zooecial meshwork heavily encrusted throughout with silicified tissue commonly extending onto sides of branches and partly filling or completely closing fenestrules. This tissue shows no fibrous texture on its surface or in cross-sections, but such texture may have been destroyed by silicification. Traces of striae are preserved, however, on parts of the inner meshwork.

Texture of silicified crust on back of zoarial meshwork, as viewed in cross sections, mottled with darker spots in lighter background or with lighter spots in darker background. In most cross sections walls between and below zooecia are dark brownish and encrusting tissue is light grayish with line of contact which may be very sharp (pl. 14, fig. 3, central part). This color differentiation suggests that zooecial walls and encrusting tissue were originally composed of fundamentally different substances.

Difference in texture and sharpness of boundary between zooecial skeleton and encrusting tissue on its reverse have been observed by Elias in many other genera of late Paleozoic fenestrate Bryozoa. The local absence of a sharp boundary has probably resulted from secondary crystallization and replacement of the original calcite.

Throughout the whole zoarium a second basket is present behind and parallel to the outer zooecia-bearing basket to which it is connected by short uprights. These arise from the encrusting tissue on the reverse of the branches of the outer meshwork (pl. 14, fig. 3) and possess a texture similar to that of the encrusting tissue just described. They are generally located opposite the middle of fenestrules rather than opposite dissepiments (pl. 15, fig. 6, right side). Because the dissepiments are commonly arranged in more or less continuous rows across the zoarium the uprights also generally occur in transverse rows (pl. 15, figs. 4, 5; pl. 16, fig. 1). The tendency for them to be arranged in longitudinal rows is somewhat less pronounced. As the uprights extend inward from the outer meshwork they deviate from perpendicular and where this deviation is pronounced they show even less regular arrangement (pl. 15, figs. 4, 5). At some places where the meshwork of the basket is sharply curved neighboring uprights may fuse (pl. 14, fig. 2, left part). At a distance of about 1.4 to 1.5 mm. from the reverse surface of the zoarial meshwork the uprights are interconnected to form the inner, nonporiferous basket. This is far less regular than the outer one but it also consists of a series of more or less longitudinal branches but the inner branches are generally variously undulating rather than straight (pl. 16, fig. 1, lower left). In spite of its greater irregularity the general pattern of the inner meshwork is

somewhat similar to that of the outer and the fenestrules of one are more or less opposite those of the other. Not uncommonly the inner fenestrules are more or less closed and the inner meshwork becomes in places a nearly or quite solid sheet.

The connecting uprights are somewhat smaller in diameter than are the branches of the outer meshwork. They are similar or slightly smaller than the branches of the inner meshwork.

The microstructure of the silicified inner basket is the same as that of the uprights and incrustation on the back of the outer meshwork but faint longitudinal striae about 0.03 mm. wide (pl. 16, fig. 1, left lower corner), suggesting a possible originally fibrous structure, can be detected on the surfaces of the inner branches. Thin white (opaque) threads are visible in the dark (translucent) background in some parts of the encrustation and of the uprights. They seem to correspond in diameter and somewhat irregular orientation to the numerous molds of threads or tubes which are preserved in an otherwise empty cast of a portion of the inner basket and uprights (pl. 15, fig. 7). These threads are generally straight to slightly curved, and vary in diameter from 0.01 to 0.035 mm., mostly about 0.02 to 0.03 mm. Some taper gradually to sharp points. The threads are loosely arranged in subparallel groups and are commonly oriented diagonally to the branches but a few extend in nearly longitudinal or nearly transverse directions. They seem to occur only in the inner part of the inner basket and of the uprights. Along the outer surfaces there was probably a layer of threads or long cell fibers oriented longitudinally, as is indicated by the surficial longitudinal striae already mentioned (pl. 16, fig. 1, left lower corner).

A few scattered thicker threads or tubes of similar appearance likewise occur generally starting from the base of a zooecium and running to the base of another zooecium or ending abruptly at the outer surface of the encrustation (pl. 15, fig. 6, near right edge), the uprights, or the inner basket. They are about as thick as the zooecial tubes from which they start, that is about 0.06 mm. in diameter, but some are larger, up to nearly 0.1 mm. in diameter. They seem to be comparable to the so-called accessory or dimorphic pores (Ulrich, 1890, p. 302) of *Septopora* (and other fenestrate bryozoa), which commonly have apertures on the reverse of the zoaria, but they also are similar in size and resemble the tubes of some stoloniferous systems which are customarily classified with the questionable ctenostomatous genus *Heteronema*.

This species is unlike most other known fossil or living Bryozoa in that it consists of two parallel and interconnected meshworks. Some fossil fenestrate Bryozoa, such as *Hemitrypa*, *Unitrypa* and others, possess a geometrically regular superstructure arising from the obverse of a meshwork like that of *Fenestella* or *Fenestrapora*. In *Bicorbula*, however, the second, somewhat irregular nonporiferous meshwork occurs in back of the zooecium-bearing meshwork with whose reverse it is connected.

Only a few species of *Polypora* are known to develop closed, cylindrical zoaria like *Bicorbula*. Cumings (1904) believed that the early zoaria of *Polypora* were cup-shaped with inward facing zooecia. He suggested that from this primitive form various foliate types of zoaria developed and that flat, foliated zoaria could have curled in reverse direction (Cumings, 1904, p. 73) and, by fusing of the lateral edges, produced cylindrical or cup-shaped zoaria with outward-facing zooecia. Elias has seen a few such cylindrical specimens of *Polypora*. One, apparently of the *P. elliptica* group from the Oread limestone of Kansas is braced by several straight pillar-like processes diagonally connecting its opposite inner sides. Another, *Polypora* cf. *cestriensis* Ulrich, in the Nebraska Geological Survey collection from the Wetumka formation, Oklahoma (pl. 13, figs. 9–10) has two broken pillar-like braces which probably connected opposite side of the cylindrical zoarium. In both the processes are developed sporadically and there is no tendency toward the development of a second meshwork, as in *Bicorbula*.

Measurements of the zooecium-bearing meshwork of *Bicorbula* do not correspond with any of the described species of *Polypora* from the Permian, but are nearest to *Polypora tripliseriata* Bassler from Timor. They are much closer, however, to measurements of *P. elliptica* of Kansas, and *P.*

borealis Stuckenberg of Russia, both from strata high in the Upper Carboniferous (table 1). It seems probable that *Bicorbula* developed from *P. elliptica* stock through development of the second meshwork in pre-Leonard, earliest Permian or latest Pennsylvanian time.

Bicorbula possibly a consortium

The presence in *Bicorbula* of an inner, nonporiferous basket parallel to the ordinary meshwork of a cylindrical zoarium is unique among known Bryozoa. A continuous regular superstructure, which might also be termed a second meshwork, occurs in the Paleozoic fenestrate genera *Hemitrypa*, *Isotrypa* and others, but in these the second meshwork is in front, not in back, of a zooecium-bearing network of *Fenestella* rather than *Polypora* type. The superstructure of *Hemitrypa* was believed by Shrubsole (1879, p. 282) to be a "small coral . . . very similar to *Flustra palmata* McCoy, the empty calices of which cover over and conceal the *Fenestella* underneath," and this explanation was accepted by Vine. Ulrich (1890, p. 354–356), however, strongly objected to this view and pointed out that in *Hemitrypa* and similar genera "structural unity" of the zoarial meshwork and the superstructure occurs and that the "little openings in the superficial net-work of *Hemitrypa* correspond . . . exactly both in position and number with the zooecial apertures beneath them in the celluliferous expansion." American and Russian students of fossil Bryozoa (also Lonsdale, Phillips and McCoy) have accepted a belief in the unity of superstructure and zooecial meshwork in *Unitrypa* and similar genera, and there seems to be no reason to doubt that superstructures of this type resulted from metabolic activity of the bryozoan colony alone. These structures consist of upward growths from the medial keels between the two rows of zooecia in the branches of the underlying meshwork either solidly or as a row of spines, which, at a uniform distance above the zooecial meshwork, are connected by transverse bars forming a perforated second meshwork parallel to the first. The superstructure is remarkable for its geometric regularity and for the precise correspondence of its pattern to the underlying meshwork and its zooecia. Perhaps the

Table 1. Measurements of Meshwork in *Bicorbula arizonica* and Comparable Species of *Polypora*

Species and Age	Branches		Fenestrules in 10 mm.	Zooecia			
	Width in mm.	Number in 10 mm.		In 5 mm.	Per fenestrule	Number of rows	
						Normally	Before bifurcation
B. arizonica Condra and Elias Kaibab locations, Middle Permian	0.35–0.7	13–16	10–12	19–20	3½	2–3	to 5
P. tripliserita Bassler Upper Permian, Timor[1]	0.4±	11–12	8– 9	16±	4	2–3	to 4
P. elliptica Rogers s.s. Kereford limestone, Oread formation, Upper Carboniferous[2]	0.4	14–16	11–12	19–20	3–5	2–3	to 4
P. borealis Stuckenberg. C^2_b, (*Cora* zone of Tschernyshew) Uralian of Timan, Russia.[3]	0.3–0.625	14–15	11–12	18	3–3+	2–3	to 5

[1] After Elias, 1937, p. 329, modified from Bassler, 1929.
[2] After Elias, 1937, p. 329.
[3] After Nikiforova, 1938, pp. 112–114, also 236–237, supplemented from a study of her illustrations.

superstructure represents excessive precipitation of calcium carbonate by a bryozoan colony comparable to extra thick shells and spines in certain races of brachiopods, echinoids and other invertebrates as well as armored plates, horns, etc. in vertebrates, a phenomenon explained by Beecher (1898). The second meshwork of *Bicorbula*, however, differs greatly from the superstructure of *Hemitrypa* and similar genera as has already been explained. Its principal differences from the superstructures of *Hemitrypa* and similar Bryozoa are (1) absence of geometrical regularity, (2) considerable variability in degree of development, such as thickness, and (3) similarity and probable identity of its anatomy to that of the encrusting tissue on the reverse of the zooecial meshwork.

Perhaps the second meshwork of *Bicorbula* also could be explained as a product of metabolic activity of a polyporid rather than a fenestellid bryozoan colony. *Polypora*-type zoaria with strong carina are unknown and this might explain why, in *Bicorbula*, excess calcium carbonate (if produced by the bryozoan colony) was precipitated to the rear and its position might also explain the irregularity of the second meshwork. If regularity of the superstructure in *Hemitrypa* and other genera reflects control of local water currents by individual polypids, it might be expected that a second meshwork behind the zooecial meshwork would be less regular because the polypids would exert less influence upon water currents moving behind the zooecial meshwork and through the fenestrules. This explanation, however, is equally applicable to an alternative hypothesis that in *Bicorbula* a second meshwork and the encrustation on the reverse of the first were produced by a symbiotic organism.

The following considerations seem to favor the latter hypothesis: (1) The second meshwork in *Bicorbula* shows a considerable degree of independence from the zooecial meshwork and does not appear to be comparable to various supporting structures and secondary calcification in living and closely related Tertiary and Cretaceous bryozoa; (2) the encrusting tissue on the back of the zooecial meshwork in *Bicorbula*, which is continued morphologically and anatomically into the second meshwork, is distinctly differentiated from material forming the walls of zooecial chambers (where the original structure is best preserved), and there is no suggestion of the so-called "basal lamella" (Canu and Bassler, 1920, p. 648) or any other feature indicating a method of development similar to the growth of various sterile dorsal supporting tissues in other living and fossil bryozoan colonies. (3) the observed structure of the encrusting tissue and of the second meshwork does not show much similarity to the structure and anatomical details of the supporting tissues in living and related Tertiary and Cretaceous Bryozoa. It does show, however, some similarity to various supporting structures of the Paleozoic fenestrate Bryozoa, the nature of which is now disputed (Condra and Elias, 1941) and increasing evidence points to the probability that they were produced by algae.

The possible phytomorph in *Bicorbula*, which produced the rear encrusting tissue and the inner meshwork connected to it,

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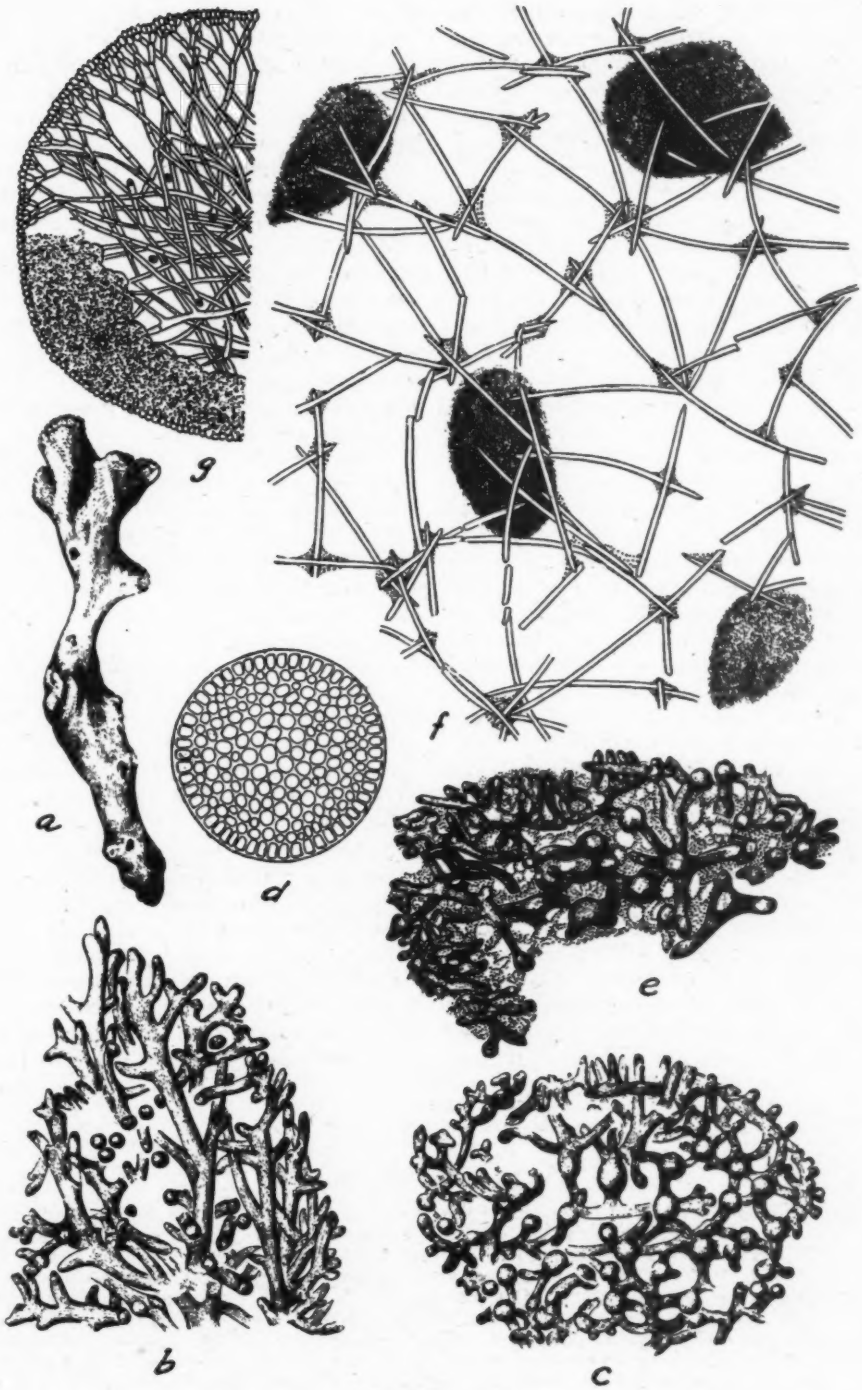
EXPLANATION OF TEXT FIGURE 1

FIGS. *a–f*—Living *Marchesettia spongiodes* (red alga) from shores of New Guinea, collected by "Gazelle" Expedition; after E. Askenasy, 1889, pl. 12. *a*, Side view of alga-sponge consortium; ×1. *b*, *c*, Views of longitudinal and transverse sections of algal symbiont, showing denser reticulation of branchlets, at periphery of colony; ×*ca.* 12. *d*, Transverse section of branchlet showing cortical layer of cells and densely packed, parallel inner hyphae; ×120. *e*, View of transverse section of consortium showing algal network and finer inserted sponge network (shown by dots); ×12. *f*, View of uniaxial siliceous spicules (monoxons) of sponge connected by soft tissue (shown by dots); large dark shaded spots represent branchlets of the alga; ×390.

g—Living *Liagora caenomyce* Decaisne, from tropical seas; after Weber van Bosse, from Pia, 1926, fig. 89-c, on p. 165; ×63. Lower area, covered by dots, indicates calcification.



TEXT FIGURE 1

seems to be comparable to some of the lower to moderately phyletically advanced living red algae. Its irregular double meshwork (one consists of the encrustation on the back of the zooecial meshwork) with short connecting uprights resembles the branching and anastomosing thallus of *Marchesettia spongiodes* (text fig. 1b and c), (Askenasi, 1899, p. 40–41; pl. XIIO), a red alga from the Indian Ocean and southwestern Pacific, which lives in intimate symbiosis with a sponge, referred to the group of *Chalinea*. These combined organisms were originally described as a sponge, *Spongia cartilaginea* Esper, but they are now known to form a consortium in which the finer three-dimensional meshwork of the sponge and the coarser of the alga are interlaced. The meshwork of *M. spongiodes* is generally irregular but tends to have a more dense and closely knit outer zone, which may be compared to the outer meshwork of *Bicorbula* and the nearly perpendicular branches of the alga are suggestive of the connecting uprights of the fossil. In *M. spongiodes*, however, the meshwork is continuous and does not enclose a hollow center as in *Bicorbula*. The branches of the meshwork in *M. spongiodes* are marked by longitudinal striae, about 0.01 to 0.015 mm. wide which correspond to the cells of the cortical layer but the corresponding striae on the *Bicorbula* are about 0.03 mm. wide. The elongated tube-like cells, or hyphae in the axial parts of the branches of *M. spongiodes* are packed closely, arranged parallel to the axis and vary in diameter from 0.01 to 0.02 mm.; inner fibers of *Bicorbula* are distributed loosely, are generally diagonally oriented, and vary in diameter from 0.01 to 0.035 mm. Such differences cannot be considered an obstacle to the interpretation that a red alga contributed to *Bicorbula;* they might be expected because the compared forms are separated by millions of years of geologic time. Threads of the Silurian *Sphaerocodium gotlandicum* are from 0.02 to 0.03 mm. thick and those of the Ordovician *Girvanella problematica* are from 0.015 to 0.04 mm. in diameter, and are rather loosely and irregularly arranged. In the living red alga *Liagora*, which has repeatedly bifurcating shoots in its youngest branches comparable in size to those of *Bicorbula*, the hyphae are loosely packed, diagonally arranged and vary from about 0.008 to 0.015 mm. in diameter, as measured on drawing by Weber van Bosse (text fig. 1, g).

There is small doubt that the basket of *Bicorbula* was calcified prior to secondary silicification (all associated fossil invertebrates from the Kaibab limestone are silicified). Living *Marchesettia* is not calcified, but *Liagora* commonly is greatly calcified with the consequent loss of most of its fine structure (text fig. 5, g). In general, the ability of algae to precipitate calcium carbonate occurs in members of all major phyletic groups, but only became stabilized in a few, e.g. in the Dasicladaceae, Corallinaceae, and others. This ability was probably less stabilized in the ancestral algal stock.

In view of these facts the conclusion seems reasonable that the apparent phytomorphic structure in *Bicorbula* was probably produced by a symbiotic alga, related to the comparatively simple Nemalionales and Cryptonemiales groups of Oltmanns (1922). If so, *Bicorbula* was a stabilized consortium of *Polypora* and a red alga. The latter is not separately named because this and othe

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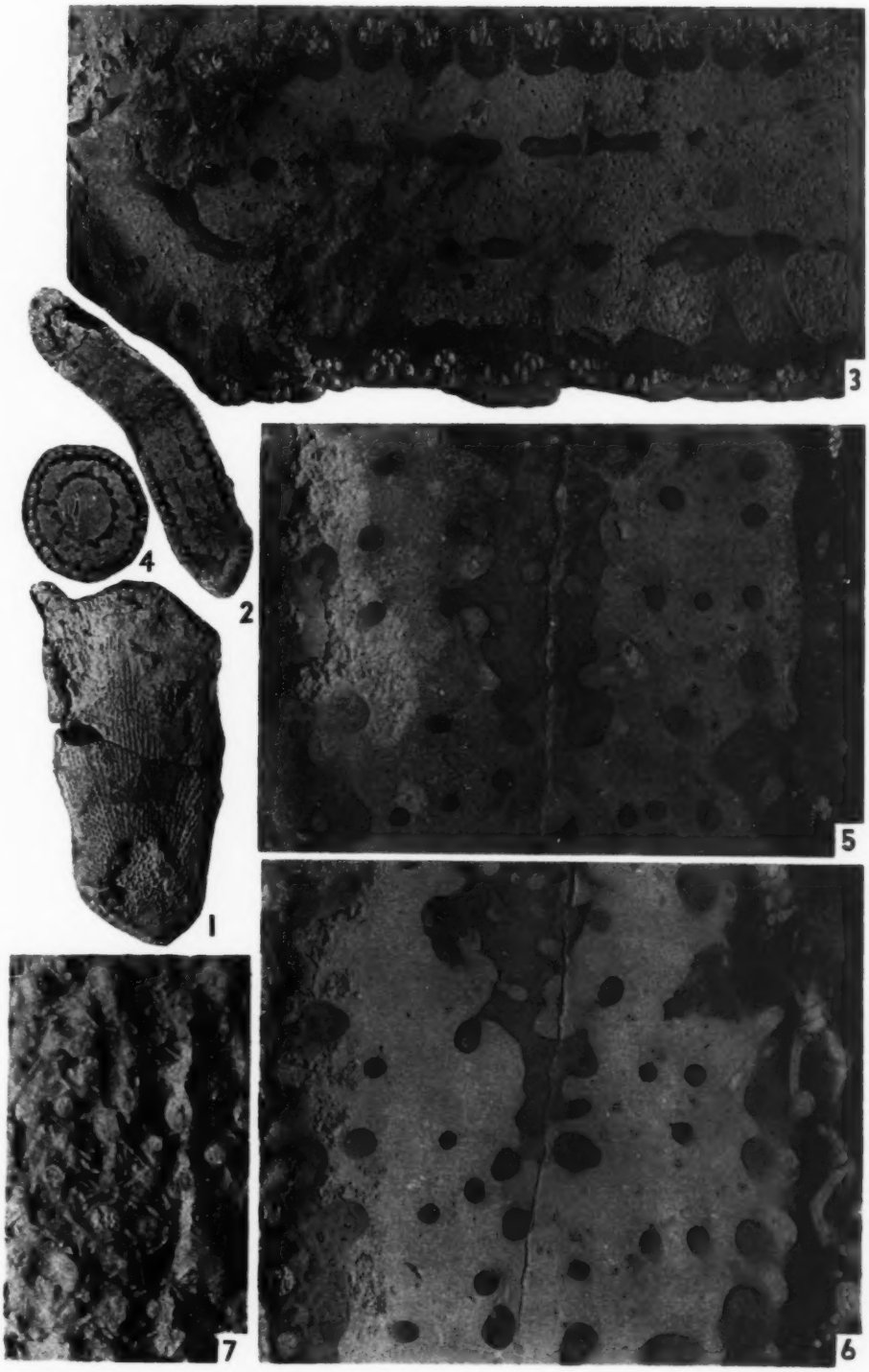
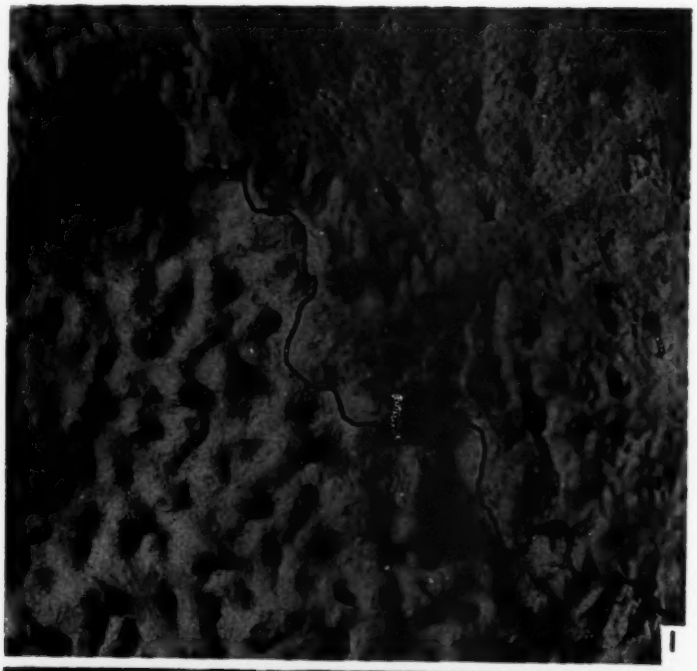
EXPLANATION OF PLATE 15

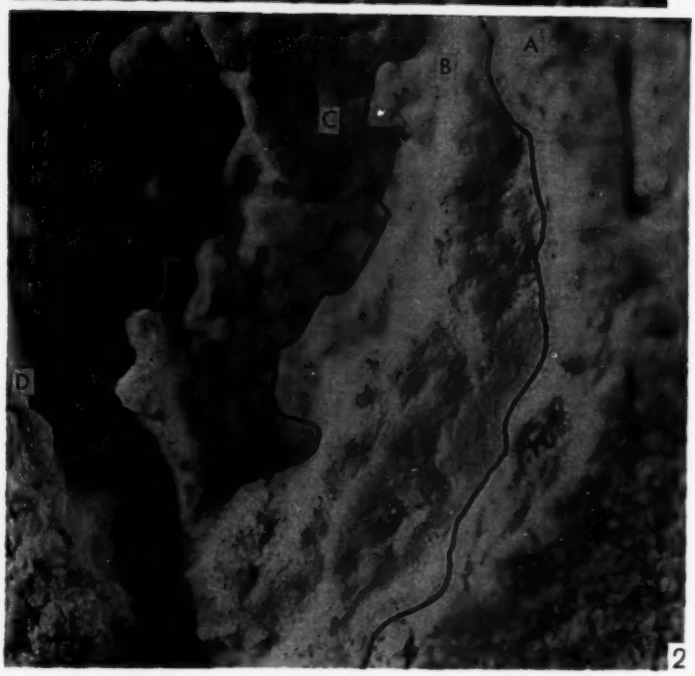
FIGS. *1–7*—*Bicorbula arizonica* Condra and Elias, n. g., n. sp., Kaibab formation, Grand Canyon, Arizona. *1–3*, Paratype N.G.S. no. 265; *1*, front view ×1; *2*, view of somewhat diagonal break in middle of specimen, along which it is cemented together ×2; *3*, same as *2*, detail ×20. *4*, Paratype N.G.S. no. 269; polished cross section of basket with nearly perfect circular cross section; ×2. *5*, *6*, Paratype, N.G.S. no. 268; two sections of same part of fossil, progressively cut, polished and photographed, showing regularity of arrangement of uprights which connect outer and inner meshwork; also showing few wide tubes starting from bases of some zooecia and extending through encrusting tissue. *7*, Paratype, N.G.S. no. 271, showing molds of finer tubes across casts of encrusting photomorph. *5*, *6*, *7*, ×20.

(p. 118)



Condra and Elias—Bicorbula





Condra and Elias—Bicorbula

possibly symbiotic algae associated with late Paleozoic Bryozoa will be described and discussed in another paper by Elias in which the consortium hypothesis for these fossil organisms will be formulated in detail.

REFERENCES

ASKENASI, E., 1899, Algen: Forschungsreise S.M.S. "Gazelle," vol. 4, Botanik, 58 pp., 12 pls.

BASSLER, R. S., 1929, Permian Bryozoa of Timor: Palaeontologie von Timor, Ergebnisse d. Exped. Molengraaff, Wanner u. Weber, vol. 26, pp. 37–90, 23 pls. (CCXXV–CCXLVII)

BEECHER, C. E., 1898. Origin and significance of spines; a study in evolution: Am. Jour. Sci., ser. 4, vol. 6, p. 1–20, 125–136, 249–268, 329–359, 1 pl., 74 text figs. (Reprinted in "Studies of evolution," pp. 3–105, New York, 1901.)

CANU, F. and BASSLER, R. S., 1920, North American Early Tertiary Bryozoa: U. S. Nat. Mus. Bull. 106, 879 pp., 279 text-figs., 162 pls.

CONDRA, G. E. and ELIAS, M. K., 1941, Study and revision of *Archimedes* (abst.): Geol. Soc. America Bull., vol. 52, p. 1963.

——, 1944, Study and revision of *Archimedes* (Hall): Geol. Soc. America Spec. Papers 53, 243 pp., 41 pls., 6 figs.

——, 1944 (A), Carboniferous and Permian ctenostomatous Bryozoa, Geol. Soc. America Bull., vol. 56.

CUMINGS, E. R., 1904, Development of some Paleozoic Bryozoa: Am. Jour. Sci., ser. 4, vol. 17, pp. 49–76, 83 text figs.

DARTON, N. H., 1925, Résumé of Arizona Geology, Arizona Univ. Bull. 119 (Geol. Ser. no. 3) 298 pp., 105 text-figs., 128 pls., 1 map.

ELIAS, M. K., 1937, Stratigraphic significance of some Late Paleozoic fenestrate bryozoans: Jour. Paleontology, vol. 11, pp. 306–334, 3 figs., 6 tables.

JOHNSON, J. H., 1942, Permian algal genus *Mizzia:* Jour. Paleontology, vol. 16, p. 63–77, pls. 9–12.

MCKEE, E. D., 1938, Environment and history of the Toroweap and Kaibab formations of Northern Arizona and southern Utah: Carnegie Inst. Washington Pub. 492, pp. viii–268, 1–35a text figs., 48 pls.

NIKIFOROVA, A., 1938, Types of Carboniferous Bryozoa of the European part of the USSR: Acad. Sci. U.S.S.R., Paleontology of USSR, vol. 4, part 5, fasc. 1; 290 p., 1–30c text-figs., 55 pls., Summary in English, pp. 205–281.

OLTMANNS, F., 1922, Morphologie u. Biologie d. Algen, Zweite Auflage, 2 Bd., Ferlag von Gustav Fisher, p. iv+439, text-figs., 288–612.

PIA, JULIUS, 1926, Pflanzen als Gesteinsbildner: Verlag von Gebrüder Borntraeger, pp. viii+355, 166 text-figs.

SCHRUBSOLE, G. W., 1879, Review of the British Carboniferous Fenestellidae: Geol. Soc. London, Quart., Jour., vol. 35, pp. 275–284.

——, 1881, Further notes on the Carboniferous Fenestellidae: Geol Soc. London, Quart. Jour., vol. 37, pp. 178–189.

STOYANOW, A. A., 1936, Correlation of Arizona Paleozoic formations: Geol. Soc. America Bull., vol. 47, pp. 459–540, 5 text-figs., 1 pl.

ULRICH, E. O., 1890, Paleozoic Bryozoa: Illinois Geol. Survey, vol. 8, pp. 285–688, pls. 29–58.

WEBER VAN BOSSE, 1921, Liste des algues du Siboga. II. Rhodophyceae, 1 Partie. Protofloridaea, Nemalionales, Cryptonemiales: Siboga-Expeditie, vol. 59b, pp. 185–310 (not seen).

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EXPLANATION OF PLATE 16

FIGS. *1–2—Bicorbula arizonica* Condra and Elias, n. g., n. sp. Details of paratype N.G.S. no. 265, see pl. 3, fig. 1. *1*, Showing obverse of the outer (zooecial) basket in the right upper diagonal half, and outer side of inner (phytomorphic) basket and broken stumps of connecting uprights, in left lower diagonal half. *2*, Showing in succession, from right lower corner to left upper corner; *A* weathered obverse of outer (zooecial) basket, *B* outer surface of inner (phytomorphic) basket; *C* inner surface of opposite part of same; and *D* inner side of outer (zooecial) basket, with broken stumps of connecting uprights, ×20. (p. 118)

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A NEW GENUS OF EARLY PALEOZOIC CEPHALOPODS FROM ALASKA

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ABSTRACT.—The generic name *Alaskoceras* is proposed for "*Plectoceras*" *sewardense* Flower from Seward Peninsula. The type specimens of this species are figured and described, and it is concluded that the beds which yielded them are probably Early Ordovician in age.

RECENTLY Flower described as "*Plectoceras*" *sewardense* two coiled nautiloids from the York district of Seward Peninsula, Alaska. He recognized that this species resembles somewhat the genotype of *Plectoceras* but is not congeneric with it. He refrained from coining a new generic name for it largely because he believed that it might be referable to one of the several genera of Canadian nautiloids that were in the process of being established. However, it is now clear that Flower's species does not belong in any of the genera known from the Canadian, or other beds. Accordingly, we here propose the name *Alaskoceras* for this form. Because only one species is being referred to the genus, it of necessity is the genotype.

The new genus includes nautiloids with slender, slightly compressed whorls that are somewhat flattened ventrally and are in contact dorsally. However, at maturity the living chamber, which occupies about half a volution, is evolute. The test bears prominent growth-lines that curve adapically on the lateral zones of the conch and form deep U-shaped ventral sinuses. Also, there are large rounded lateral ribs parallel to the growth-lines. The camerae are short, and the sutures form very shallow lateral lobes and dorsal and ventral saddles. The siphuncle is small, is ventral and marginal in position, is composed of almost cylindrical segments, and presumably is orthochoanitic in structure.

This genus is perhaps closest to *Plectoceras* Hyatt, of which the genotype is *Nautilus jason* Billings of the Chazyan Mingan formation of eastern Quebec (and possibly equivalent beds in northeastern New York). However, in typical *Plectoceras* the whorls are expanded orad much more rapidly than are those of *Alaskoceras;* the adapical portion of the conch is loosely coiled; the living chamber of large specimens does not become markedly evolute; and the siphuncle is considerably removed from the ventral wall of the conch. Many of the species that are now referred to *Plectoceras* may prove not to be congeneric with its genotype, but none of them seems to be particularly close to the type species of *Alaskoceras*. However, all of them, as well as typical *Plectoceras* and *Alaskoceras*, should be placed in the Plectoceratidae.

Insofar as we have been able to ascertain, little information is available in regard to the age of the beds that yielded the type specimens of *Alaskoceras sewardense*. The field label that accompanies the holotype states that it is "Ordovician?" in age. Traces of fossils in the block of limestone in which the paratype is imbedded do not help to fix its age. Because *Alaskoceras sewardense* is a unique form, being the only known representative of a genus, its stratigraphical significance is at present limited, and it indicates the age in only a general way. The family in which it belongs ranges throughout much of the Ordovician. It is represented in the Canadian by only one genus, is not rare in the Chazyan, and is fairly abundant and widespread in the Mohawkian of America, at least. However, in general physiognomy, the species under consideration resembles Canadian and Chazyan species much more closely than those known from younger strata. Therefore, we are tentatively regarding it as Early Ordovician in age but we recognize, of course, that it is rarely possible to make an accurate age determination from a single species.

Alaskoceras sewardense (Flower)
Plate 17, figures 1–6

"*Plectoceras*" *sewardense* FLOWER, 1941, Bull. Am. Paleontology, vol. 27, no. 102, pp. 6, 14–17, pl. 2, figs. 1, 2.

The holotype of this species represents most of the conch and is moderately well preserved. However, it is considerably weathered, and its left side is incomplete. The paratype is a polished longitudinal section imbedded in a dense dark gray limestone that contains traces of other fossils. Both of the type specimens are of similar lithology.

The conch of the holotype consists of slightly more than three volutions. The adoral half of the outer volution represents the living chamber and is considerably evolute, but the rest of the whorls are in contact though not impressed dorsally. The living chamber of this specimen appears to be essentially complete adorally, and it is about 95 mm. long. Near its adoral end it is about 31 mm. high and about 27 mm. wide, and its dorsal side is some 15 mm. from the ventral side of the preceding volution. The cross section of the conch at this place is ovate as it is slightly compressed and is more broadly rounded ventrally than dorsally—its ventral zone is distinctly flattened. Near the adoral end of the penultimate volution of this specimen the conch is about 17 mm. high and about 15.5 mm. wide. A comparison of these figures with the corresponding dimensions of the outer volution shows that the conch is expanded orad very gradually, and its rate of adoral expansion seems to be fairly constant throughout its entire length. However, the adapical portion of the conch is less strongly compressed than is the adoral, and the amount of ventral flattening decreases adapically.

The umbilicus is very broad and shallow, and the umbilical shoulders are rounded and indefinite. The extreme adapical portion of the holotype is poorly preserved, but if an umbilical perforation exists it is very small. The test is thick, and on the living chamber of both types, mature specimens, averges about 1½ mm. in thickness. The surface of the test bears prominent growth-lines which form deep rounded U-shaped ventral sinuses and broad shallow lateral salients that are not quite normal to the long axis of the conch. Also, at least the outer volution of the phragmacone of the holotype bears large oblique ribs which are parallel to the growth-lines and are largely confined to the lateral zones of the conch. These ribs end rather abruptly on the ventrolateral and, to a lesser extent, on the dorsolateral zones of the conch. They are prominent on the internal mold as well as on the exterior of the test.

On the adoral portion of the phragmacone the sutures form broad, shallow, rounded lateral lobes and similar dorsal and ventral saddles. The camerae are short and, where the conch of the paratype is about 20 mm. high, they average about 3 mm. in length. In the extreme adoral portion of the phragmacone of the paratype the camerae are very short (only about half their normal length), indicating that the specimen represents a mature individual. The adoral camera of the holotype is almost 3 mm. long.

The siphuncle is ventral and marginal in position and apparently is in contact with the ventral wall of the conch. It is moderate in size and in the adoral portion of the phragmacone of both type specimens attains a diameter of some 3½ mm. The segments of the siphuncle are essentially cylindrical but are very slightly concave exteriorly. Presumably, the structure of the siphuncle is orthochoanitic, but the length of the septal necks and the connecting rings is not known. The walls of the siphuncle attain a thickness of about 0.5 mm.

Remarks.—Both of the type specimens are of the same general size and shape, though the paratype seems to have been somewhat distorted during preservation. Superficially this form resembles certain species now referred to *Plectoceras*, but it is readily differentiated from them by the fact that its conch is less rapidly expanded orad and at maturity its living chamber is evolute.

Flower (1941, p. 6) has illustrated diagrammatically the siphuncle of the species under consideration as being distinctly removed from the ventral wall of the conch, but in his specific description he states that it "lies in contact with the venter at least in the last [outer] whorl." Our observations confirm his statement but not his illustra-

tion. Furthermore, we are not able to differentiate septal necks and connecting rings, or to determine the size of the umbilical perforation; and we differ from Flower in regard to the shape of the sutures, which, however, are none too clear on the holotype and cannot be seen at all on the paratype.

Occurrence.—Both of the known representatives of this species were collected in 1940 by J. B. Mertie, Jr., from the Early Paleozoic of the York district, Seward Peninsula, Alaska. The holotype came from the crest of the ridge between Cassiterite Creek and Lost River, about 5000 feet N. 12° W. of Cassiterite Mine; whereas the paratype was found "in place" in the bed of Rapid River about 3500 feet from its mouth.

Types.—U. S. National Museum.

MANUSCRIPT RECEIVED JANUARY 25, 1943.

REFERENCES

FLOWER, R. H., 1941, Cephalopods from the Seward Peninsula of Alaska: Bull. Am. Paleontology, vol. 27, no. 102, pp. 1–22, pls. 1, 2.

FOERSTE, AUG. F., 1932, Black River and other cephalopods from Minnesota, Wisconsin, Michigan, and Ontario (pt. I): Denison Univ. Bull., Jour. Sci. Labs., vol. 27, pp. 47–136, pls. 7–37.

RUEDEMANN, RUDOLF, 1906, Cephalopoda of the Beekmantown and Chazy formations of the Champlain basin: New York State Mus. Bull. 90, pp. 389–611, pls. 1–38.

ULRICH, E. O., FOERSTE, AUG. F., MILLER, A. K., and FURNISH, W. M., 1942, Ozarkian and Canadian cephalopods; pt. I, Nautilicones: Geol. Soc. America Spec. Paper 37, pp. 1–157, pls. 1–57.

EXPLANATION OF PLATE 17

FIGS. *1–6*—*Alaskoceras sewardense* (Flower) from the Early Paleozoic of the York district, Seward Peninsula, Alaska. *1*, Median longitudinal section of midportion of outer volution of phragmacone of paratype, shows size, shape, and position of siphuncle, ×2. *2–6*, Holotype, ×1 (except figure 6, which is ×2). *4*, Side of conch opposite to that illustrated by figure 2, shows lateral ribs on adoral portion of outer volution of phragmacone—dorsal portion of this volution has been abraded and polished in an attempt to locate siphuncle. *6*, Surface of test on ventral side of adoral end of penultimate volution of specimen. (p. 127)

Miller and Kummel—Alaskan Cephalopods

JOURNAL OF PALEONTOLOGY, VOL. 19, NO. 2, PP. 129–148, PLS. 18–21, 2 TEXT FIGS., MARCH 1945

DIAGNOSTIC FORAMINIFERA FROM SUBSURFACE FORMATIONS IN FLORIDA

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ABSTRACT.—Forty species of Foraminifera are described from Tertiary and Cretaceous formations in Florida, and lists of additional species common in the same formations are presented.

INTRODUCTION

THE SUBSURFACE formations of Florida contain a rich fauna of microfossils, of which most of the species and some of the genera are either new, or have not been recorded from other parts of North America. In this paper the writers describe 40 common and diagnostic species of Foraminifera chosen from beds ranging in age from Upper Cretaceous to Oligocene. Since the paper is mainly concerned with the description of new species, lists of previously described characteristic forms are also included, and for the convenience of the economic geologist, titles of readily available papers in which these fossils are figured and discussed have been added. As an aid to the economic paleontologist also, the exterior aspects of the forms are emphasized in the descriptions and figures.

ACKNOWLEDGMENTS

The authors are greatly indebted to Dr. Joseph A. Cushman, who was consulted in regard to the generic determinations of several of the species described, and who kindly assisted in the comparison of specimens with types and topotypes in his collections. The writers also wish to express their gratitude to Lloyd G. Henbest and to Dr. T. Wayland Vaughan, who gave much time to the study of some of the forms and furnished helpful comments in regard to them. Thanks are also due Mr. Herman Gunter, Director of the Florida Geological Survey, who supplied a large part of the well sample material used in studies connected with this paper.

Photographs for the illustrations were made by Dr. J. A. Cushman, and drawings by Miss Louise Jordan, of the Sun Oil Company.

Holotypes and paratypes of new species and varieties, and plesiotypes of described forms are deposited at the United States National Museum in Washington, D. C. Sets of topotypes will be placed in Cushman's Laboratory of Foraminiferal Research at Sharon, Mass., and with the collections of the Florida Geological Survey at Tallahassee, Florida.

This paper is published by permission of the Director of the United States Geological Survey, and the Director of the Florida Geological Survey.

LIST OF COMMON AND CHARACTERISTIC SPECIES OF FORAMINIFERA IN FLORIDA FORMATIONS

SUWANNEE LIMESTONE (OLIGOCENE)

Asterigerina subacuta floridensis, n. var.
This paper. and Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 1, figs. 3a, b, 1944.

Coskinolina floridana Cole.
Florida Geol. Survey Bull. 19, pp. 24–25, pl. 3, figs. 1–7; pl. 4, figs. 1–9; pl. 5, figs. 1–5, 11; pl. 18, fig. 9, 1941.

Dictyoconus cookei (Moberg).
Idem., pp. 26–27, pl. 3, figs. 11–13; pl. 5, figs. 6–10, 12, 13; pl. 6, figs. 1–8; pl. 18, fig. 12.

Elphidium leonensis, n. sp.
This paper.

Elphidium aff. E. poeyanum (d'Orbigny).
U. S. Geol. Survey Prof. Paper 189, p. 106, pl. 25, figs. 5, 7, 1938.

Heterostegina texana Gravell and M. A. Hanna.
Florida Geol. Survey Bull. 19, p. 33, pl. 10, figs. 8, 9; pl. 11, figs. 1, 2, 1941.

Miogypsina (*Miogypsina*) *gunteri* Cole.
Idem. pp. 43, 44, pl. 7, figs. 5–7.

Nonion advenum (Cushman).
U. S. Geol. Survey Prof. Paper. 189, p. 106, pl. 24, figs. 22, 23, 1938.

Nonionella leonensis, n. sp.
This paper.

Operculinoides vicksburgensis Vaughan and Cole.
Florida Geol. Survey Bull. 26, pp. 49, 50, pl. 3, figs. 7, 10; pl. 6, figs. 1–5, 11, 12, 15, 17, 18; pl. 19, fig. 11, 1944.

Quinqueloculina leonensis, n. sp.
This paper.

Rotalia byramensis Cushman.
This paper, and Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 1, figs. 1a, b, 1944.

Rotalia mexicana Nuttall.
Jour. Paleontology, vol. 2, p. 374, pl. 50, figs. 6–8, 1928.

Rotalia mexicana mecatepecensis Nuttall.
Jour. Paleontology, vol. 6, p. 26, pl. 4, figs. 11–12, 1932.
Valvulammina? sp.
U. S. Geol. Survey Prof. Paper 189, p. 104, pl. 24, figs. 2, a, b, c, 1938.

BEDS OF VICKSBURG AGE (OLIGOCENE)

Cibicides mississippiensis (Cushman).
Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 5, fig. 6, a, b, 1933.
Cibicides pseudoungerianus (Cushman).
Idem. pl. 5, figs. 3, 4, a, b.
Eponides byramensis (Cushman).
U. S. Geol. Survey Prof. Paper 129, p. 99, pl. 22, figs. 4, 5, 1921.
Lepidocyclina (*Lepidocyclina*) *mantelli* Morton.
U. S. Geol. Survey Prof. Paper 125, pp. 57–60, pls. 12–14, 1920; and Florida Geol. Survey Bull. 26, pp. 70–71, pl. 19, fig. 5; pl. 22, figs. 13–15, 1944.
Liebusella byramensis turgida Cushman.
U. S. Geol. Survey Prof. Paper 181, p. 11, pl. 2, fig. 9, 1935.
Operculinoides dius (Cole and Ponton).
Florida Geol. Survey Bull. no. 5, 1930, p. 37, pl. 6, fig. 7, pl. 7, figs. 11–13.
Robulus vicksburgensis (Cushman).
Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 2, fig. 2, 1933.
Uvigerina vicksburgensis Cushman and Ellisor.
Cushman Lab. Foram. Research Contr., vol. 14, pt. 4, p. 76, pl. 13, figs. 10, 11, 1938.

OCALA LIMESTONE OF JACKSON AGE (UPPER EOCENE)

Amphistegina alabamensis, n. sp.
This paper.
Cibicides mississipiensis ocalanus Cushman.
This paper; U. S. Geol. Survey Prof. Paper 181, p. 54, 1935.
Discocyclina (*Asterocyclina*) *nassauensis* Cole.
Florida Geol. Survey Bull. 26, pp. 79–81, pl. 1, fig. 16; pl. 12, figs. 5, 6; pl. 24, figs. 1–8, 1944.
Eponides jacksonensis (Cushman and Applin).
U. S. Geol. Survey Prof. Paper 181, p. 46, pl. 19, figs. 4–8, 1935.
Gypsina globula (Reuss).
Idem, p. 54, pl. 23, figs. 4, 5.
Heterostegina ocalana Cushman.
Florida Geol. Survey Bull. 19, pp. 32, 33, pl. 11, figs. 3–6, 1941.
Lepidocyclina (*Lepidocyclina*) *ocalana* Cushman.
Florida Geol. Survey Bull. 19, pp. 41–43, pl. 13, figs. 1–7; pl. 16, figs. 1–4, 6–10, 15, 1941 Note—Several varietal forms of this species are also common in the Ocala limestone. These have been figured and discussed in the above mentioned paper.
Nonion chapapotensis Cole.
Florida Geol. Survey Bull. 19, pp. 30, pl. 11, figs. 13, a, b, 1941.
Operculina mariannensis Vaughan.
Am. Assoc. Petroleum Geologists Bull., vol. 22, no. 8, pl. 4, fig. 10, 1938.
Operculinoides floridensis (Heilprin).
Florida Geol. Survey Bull. 19, pp. 30, 31, pl. 9, fig. 8, pl. 10, figs. 1–3, 1941.
Operculinoides ocalanus (Cushman).
Idem, pp. 31, 32, pl. 10, figs. 4–7.
Operculinoides willcoxi (Heilprin).
Idem, p. 32, pl. 9, figs. 1–7.
Pseudophragmina (*Proporocyclina*) *citrensis* (Vaughan).
Florida Geol. Survey Bull. 26, pp. 83–84, pl. 1, fig. 9; pl. 18, fig. 10; pl. 25, figs. 1–6; pl. 28, fig. 6, 1944.
Reusella eocena (Cushman).
U. S. Geol. Survey Prof. Paper 181, p. 38, pl. 15, figs 4, 5, 1935.
Reusella sculptilis (Cushman).
Idem, p. 38, pl. 15, figs. 6, 7.

LOWER MEMBER OF OCALA LIMESTONE

This member of the Ocala limestone is characterized by an abundance of miliolid Foraminifera, most of which are as yet undescribed. It differs from the upper member, also in the scarcity of larger Foraminifera, of which few species and usually few specimens, are present.

The lower member of the Ocala is clearly defined in nearly all well sections studied from the peninsular area of Florida, but could not be distinguished from the upper member in northern Florida and southern Georgia, where lower and upper species seem to mingle in a relatively thin Ocala section.

A good outcrop of the lower member of the Ocala was found in a drainage ditch which crosses highway 16A, north of Inglis, near the power plant on the north side of the road, in Levy County, Florida.

Amphistegina pinarensis cosdeni, n. var.
This paper, and Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 2, figs. 2a, b, and 3, 1944.
Camerina aff. *C. vanderstoki* (Rutten and Vermunt).
This paper.
Nonion advenum (Cushman).
U. S. Geol. Survey Prof. Paper 181, p. 30, pl. 11, figs. 1, 2, 3, 1935. Note—Present also in upper member, but less abundant.
Rotalia cushmani, n. sp.
This paper, and Idem, p. 46, pl. 19, fig. 11a–c.
Spiroloculina seminolensis, n. sp.
This paper.

AVON PARK LIMESTONE (LATE MIDDLE EOCENE)

Coskinolina floridana Cole.
Florida Geol. Survey Bull. 19, pp. 24, 25, pl. 3, figs. 1–7; pl. 4, figs. 1–9; pl. 5, figs. 1–5; 11; pl. 18, fig. 9. 1941.
Cribrobulimina cushmani, n. sp.
This paper.
Cyclammina watersi, n. sp.
This paper.
Dictyoconus cookei (Moberg).
Florida Geol. Survey Bull. 20, pp. 24, 25, pl. 3, fig. 10; pl. 4, fig. 8, 1942.
Discorinopsis gunteri Cole.
Florida Geol. Survey Bull. 19, pp. 36–37, pl. 1, figs. 7–9, 1941.
Flintina avonparkensis, n. sp.
This paper.
Lituonella floridana Cole.
Florida Geol. Survey Bull. 19, p. 23, pl. 3, figs. 14–17 pl. 4, fig. 10, pl. 6, figs. 9–11, 1941.
Rotalia avonparkensis, n. sp.
This paper.
Spirolina coryensis Cole.
Florida Geol. Survey. Bull. 19, 1941, pp. 33, 34, pl. 1, figs. 5, 6.
Textularia coryensis Cole.
Idem, p. 21, pl. 1, fig. 13.
Valvulammina minuta, n. sp.
This paper.
Valvulina avonparkensis, n. sp.
This paper.

Valvulina intermedia, n. sp.
This paper.
Valvulina martii Cushman and Bermudez.
Cushman Lab. Foram. Research Contr., vol. 13, pt. 1, p. 7; pt. 2, pl. 5, fig. 1 a, b, 1937.

LAKE CITY LIMESTONE
(EARLY MIDDLE EOCENE)

Amphistegina lopeztrigoi D. K. Palmer.
Jour. Paleontology, vol. 10, p. 233, pl. 30, figs. 1, 2; pl. 32, figs. 1–3; pl. 34, fig. 1, pl. 38, fig. 3, 1936.
Amphistegina nassauensis, n. sp.
This paper.
Archaias columbiensis n. sp.
This paper.
Asterigerina cedarkeysensis Cole.
Florida Geol. Survey Bull. 20, pp. 32, 33, pl. 1, figs. 9–10, 1942.
Dictyoconus americanus (Cushman).
Idem, pp. 21–24, pl. 3, figs. 12, 13; pl. 6, figs. 1–9; pl. 7, figs. 1–5; pl. 16, figs. 14, 15.
Discocyclina (*Asterocyclina*) *monticellensis* Cole and Ponton.
Florida Geol. Survey Bull. 26, pp. 76–79, pl. 1, fig. 8; pl. 2, fig. 11; pl. 8, fig. 23; pl. 13, fig. 5; pl. 23, figs. 1–12, 1944. Note.—This form has been found in a well in northeastern Florida, and is common near the top of the section across northern Florida.
Discorbis inornatus Cole.
Florida Geol. Survey Bull. 20, pp. 30–31, pl. 1, figs. 1–3, 1942.
Eodictyoconus cubensis (Cushman and Bermudez).
Bull. Am. Paleontology, vol. 28, no. 113, p. 6, pl. 1, fig. 1; pl. 2, figs. 1–12; pl. 3, figs. 1–5, 1944.
Epistomaria semimarginata (d'Orbigny).
This paper.
Eponides gunteri Cole.
Florida Geol. Survey Bull. 20, pp. 31, 32, pl. 1, figs. 4, 6. (not fig. 5), 1942.
Fabularia gunteri, n. sp.
This paper.
Fabularia vaughani Cole and Ponton.
Am. Midland Naturalist, vol. 15, pp. 139–141, pl. 1, figs. 1–9, 1934, and Florida Geol. Survey Bull. 20, p. 25, pl. 3, fig. 14; pl. 15, fig. 1, 1942.
Gunteria floridana Cushman and Ponton.
Cushman Lab. Foram. Research Contr., vol. 9, pp. 25–30, pl. 3, figs. 1–3, 1933.
Lepidocyclina (*Polylepidina*) *antillea* Cushman.
Florida Geol. Survey Bull. 26, pp. 57–60, pl. 1, figs. 18, 19; pl. 6, figs. 10, 16; pl. 10, figs. 1–8; pl. 11, figs. 1–9; pl. 12, figs. 1–4; pl. 13, fig. 4, 1944. Note.—This form has been found in a well in northeastern Florida and is common at the top of the section across northern Florida.
Lepidocyclina (*Pliolepidina*) *cedarkeysensis* Cole.
Florida Geol. Survey Bull. 20, pp. 43–45, pl. 3, figs. 1, 2; pl. 8, fig. 11; pl. 11, figs. 6, 7; pl. 12, figs. 1–7, 1942.
Linderina floridensis Cole.
Idem, pp. 36, 37, pl. 11, fig. 8; pl. 15, figs. 7–11.
Lockhartia cushmani, n. sp.
This paper.
Operculinoides jennyi Barker.
Florida Geol. Survey Bull. 26, pp. 45, 46, 47, pl. 1, figs. 1, 2; pl. 7, figs. 4, 11; pl. 17, figs. 1–3, 1944.

OLDSMAR LIMESTONE (LOWER EOCENE)

Clavulina floridana Cole.
Florida Geol. Survey Bull. 20, p. 17, pl. 2, figs. 6, 7, 1942.
Coskinolina elongata Cole.
Idem, pp. 20, 21, pl. 3, figs. 15–17; pl. 4, figs. 1–3; pl. 5, figs. 2–7; pl. 16, fig. 6.
Helicostegina gyralis Barker and Grimsdale.
Jour. Paleontology, vol. 10, pp. 236, 237, pl. 30, figs. 3–5; pl. 32, figs. 4, 5; pl. 34, figs. 2–6; pl. 37, fig. 6, 1936.
Lituonella elegans Cole.
Florida Geol. Survey Bull. 20, p. 19, pl. 3, fig. 7, pl. 5, figs. 9, 10; pl. 16, figs. 5, 9, 1942.
Lockhartia cushmani, n. sp.
This paper.
Miscellanea nassauensis, n. sp.
This paper.
Miscellanea nassauensis var. *reticulosus*, n. var.
This paper.
Pseudophragmina (*Proporocyclina*) *cedarkeysensis* Cole.
Florida Geol. Survey Bull. 26, pp. 81–83, pl. 2, fig. 13, pl. 18, fig. 9; pl. 26, figs. 1–4; pl. 27, figs. 1–2, 1944.

CEDAR KEYS LIMESTONE (PALEOCENE)

Borelis floridanus Cole.
Florida Geol. Survey Bull. 26, p. 53, pl. 9, figs. 1–5, 1944.
Borelis gunteri Cole.
Florida Geol. Survey Bull. 19, p. 34, pl. 2, figs. 1–3, pl. 18, figs. 5, 6, 1941.
Cribrospira? bushnellensis, n. sp.
This paper.
Planispirina? kissengenensis, n. sp.
This paper.
Valvulammina nassauensis, n. sp.
This paper.

BEDS OF TAMESÍ (VELASCO) AGE
(PALEOCENE)

Across northern Florida, at least as far east as Wakulla County, a microfauna which is closely similar to that of the Tamesí of Mexico, and which also shows relationships to the faunas of the Porters Creek and the Naheola formations of Alabama takes the place of the Cedar Keys limestone fauna in the section.

Ammodiscus incertus (d'Orbigny).
Texas University Bull. 2644, p. 63, pl. 13, figs. 1, a–d, 1927.
Anomalina rubiginosa Cushman.
This paper.
Bulimina (*Desinobulimina*) *quadrata* Plummer.
Cushman Lab. Foram. Research Contr., vol. 16, pt. 3, p. 67, pl. 11, fig. 21, 1940.
Cibicides cognatus Galloway and Morrey.
Jour. Paleontology, vol. 5, no. 4, p. 345, pl. 39, figs. 5 a–c, 1931.
Clavulinoides midwayensis Cushman.
Cushman Lab. Foram. Research Contr., vol. 16, pt. 3, p. 53, pl. 9, fig. 6, 1940.
Dorothia alabamensis Cushman.
Idem, pp. 53, 54, pl. 9, fig. 7.
Eponides waltonensis, n. sp.
This paper.
Gaudryina sp. Cushman.
Cushman Lab. Foram. Research Contr., vol. 16, pt. 3, p. 53, pl. 9, fig. 5, 1940.
Globigerina cretacea d'Orbigny.
Jour. Paleontology, vol. 2, no. 3, p. 193, pl. 27, fig. 15, 1928.
Globigerina pseudo-bulloides Plummer.
Cushman Lab. Foram. Research Contr., vol. 18, pt. 2, p. 43, pl. 8, figs. 3, 4, 1942.
Globigerina triloculinoides Plummer.
Idem, p. 43, pl. 8, figs. 1, 2.
Globigerina velascoensis Cushman.
This paper.
Globorotalia cf. G. membranacea (Ehrenberg).
Cushman Lab. Foram. Research Contr., vol. 18, pt. 2, p. 45, 1942.

Globorotalia velascoensis (Cushman).
This paper.
Gyroidina sparksi White.
Jour. Paleontology, vol. 2, no. 4, p. 297, pl. 40, fig. 8, 1928.
Gyroidina subangulata (Plummer).
Cushman Lab. Foram. Research Contr., vol. 16, pt. 3, p. 71, pl. 12, fig. 7, 1940.
Marssonella oxycona floridana, n. var.
This paper, and Cushman Lab. Foram. Research Spec. Pub. 8, p. 56, pl. 6, fig. 9a, 1937.
Planulina waltonensis, n. sp.
This paper.
Pseudoglandulina manifesta (Reuss).
Cushman Lab. Foram. Research Contr., vol. 16, pt. 3, p. 60, pl. 11, fig. 1, 1940.
Pullenia quinqueloba Reuss.
Idem, p. 72, pl. 12, figs. 13, 14.
Pulvinulinella obtusa (Burrows and Holland).
Cushman Lab. Foram Research Contr., vol. 18, pt. 2, p. 42, pl. 7, figs. 19–20, 1942.
Trochamminoides irregularia White.
Jour. Paleontology, vol. 2, no. 4, p. 307, pl. 42, fig. 1, 1928.
Vaginulina robusta Plummer
Cushman Lab. Foram. Research Contr., vol. 16, pt. 3, p. 61, pl. 10, figs. 1–4, 1940.
Valvulineria allomorphinoides (Reuss).
Idem, pp. 70, 71, pl. 12, fig. 9.

LAWSON LIMESTONE (UPPER CRETACEOUS)

The Lawson limestone represents the youngest beds of Cretaceous age present in peninsular Florida. It can be separated into two parts. The upper member is sparsely fossiliferous, and the fauna is also very poorly preserved. It contains specimens of *Vaughanina* sp., an undescribed rotaliid form and *Pseudorbitoides?* sp. Cole. The latter was discussed and figured in Florida Geol. Survey Bull. 26, pp. 56, 57, pl. 2, figs. 4. 9, 10; pl. 21, fig. 12, 1944. The lower member has a distinctive, easily recognized fauna in which the following species are common to abundant.

Cibicides harperi (Sandidge).
This paper.
Lepidorbitoides (*Asterorbis*) *aguayoi* D. K. Palmer.
Florida Geol. Survey Bull. 20, pp. 40–42, pl. 3, figs. 3, 6; pl. 10, figs. 2–5, 1942.
Lepidorbitoides (*Lepidorbitoides*) *minima* H. Douville.
Idem, p. 39, pl. 3, fig. 9; pl. 9, figs. 2, 3, 12–14; pl. 11, fig. 2.
Lepidorbitoides (*Lepidorbitoides*) *nortoni* (Vaughan).
Florida Geol. Survey Bull. 19, pp, 40, 41, pl. 12, figs. 1–8, 1941.
Lepidorbitoides (*Lepidorbitoides*) *planasi* M. G. Rutten.
Florida Geol. Survey Bull. 20, pp. 39, 40, pl. 3, fig. 5, pl. 8, fig. 12; pl. 9, figs. 4, 7–11; pl. 11, figs. 1, 3, 1942.
Loxostoma clavatum (Cushman).
Jour. Paleontology, vol. 6, no. 4, p. 340, pl. 51, figs. 8 a, b, 1932.
Robulus münsteri (Roemer).
Jour. Paleontology, vol. 6, no. 4, p. 334, pl. 50, figs. 2 a, b, 1932.
Sulcoperculina cosdeni, n. sp.
This paper, and Am. Assoc. Petrol. Geol. Bull., vol. 28, pl. 5, fig. 5, 1944.

SPECIES COMMON IN BEDS OF TAYLOR AGE ON PENINSULAR FLORIDA

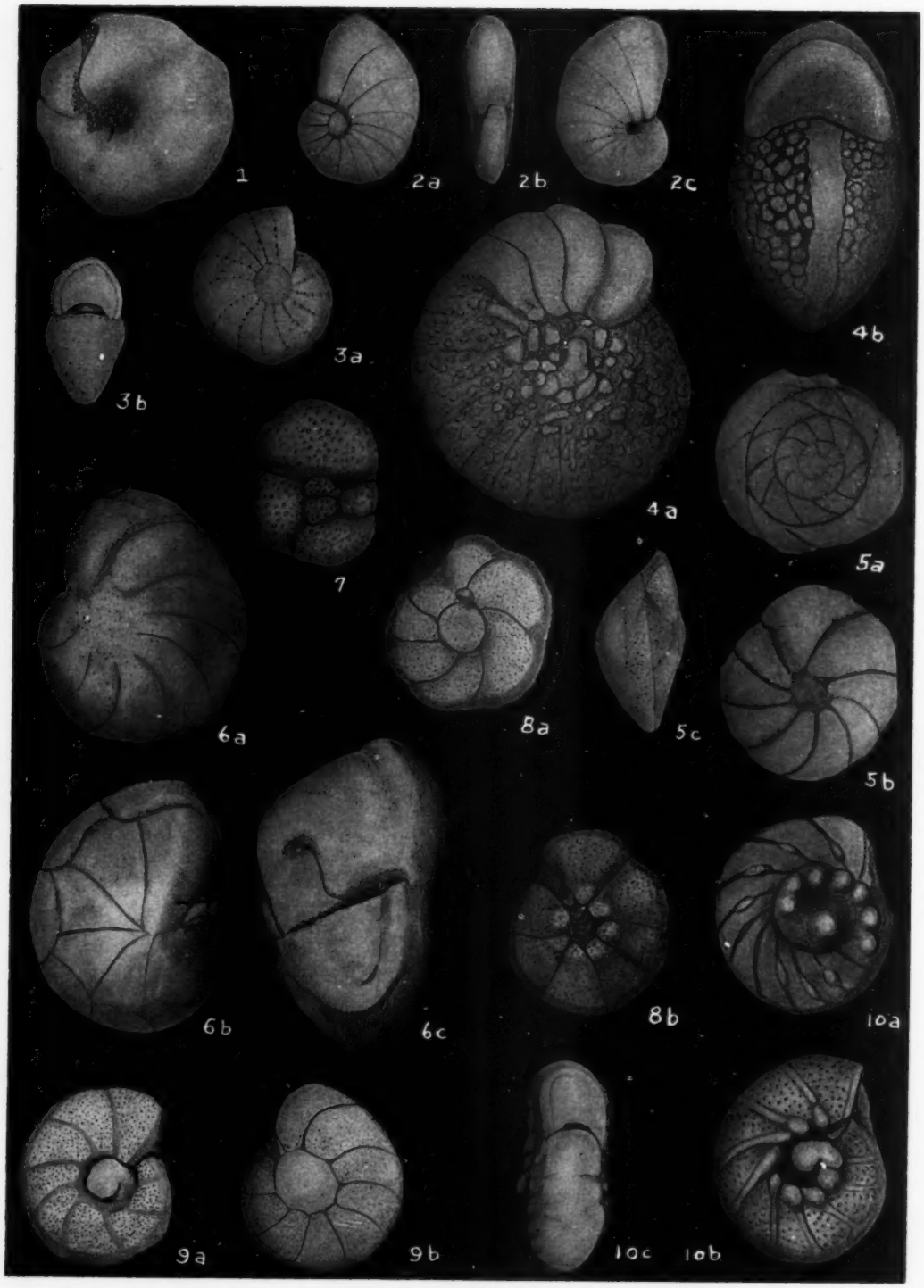
In a downward sequence of samples the top of beds of Taylor age may usually be recognized by the first appearance of an abundance of fragments of *Inoceramus*.

Anomalina cosdeni, n. sp.
This paper.
Anomalina scholtzensis Cole.
Florida Geol. Survey Bull. 20, pp. 34, 35, pl. 2, figs. 1, 2, 1942.
Bolivina incrassata Reuss.
Jour. Paleontology, vol. 6, no. 3, p. 381, pl. 41, fig. 21, 1932.
Bolivinoides decorata (Jones).
Florida Geol. Survey Bull. 16, pl. 4, fig. 9, 1938.
Buliminella cushmani Sandidge.
Jour. Paleontology, vol. 6, no. 3, p. 280, pl. 42, figs. 18, 19, 1932.

EXPLANATION OF PLATE 18

FIGS. *1*—*Cibrospira? bushnellensis* Applin and Jordan, n. sp. ×36. Holotype no. 559689. (p. 133)
2—*Cyclammina watersi* Applin and Jordan, n. sp. ×43. *a*, Side view; *b*, apertural view of holotype no. 559690. (p. 133)
3—*Valvulina avonparkensis* Applin and Jordan, n. sp. ×45. Holotype no. 559691. (p. 134)
4—*Valvulina intermedia* Applin and Jordan, n. sp. ×30. Holotype no. 559692 (p. 134)
5—*Cribrobulimina cushmani* Applin and Jordan, n. sp. *a*, Holotype no. 559694, ×20; *b*, paratype no. 559693, ×30. (p. 134)
6—*Valvulammina minuta* Applin and Jordan, n. sp. *a*, Dorsal view, *b*, side view of holotype no. 559695; *c*, ventral view of paratype no. 559696; ×60. (p. 135)
7—*Valvulammina nassauensis* Applin and Jordan, n. sp. *a*, Dorsal view of holotype no.559697, ×26; *b*, ventral view of paratype no. 559698, ×43. (p. 135)
8—*Amphistegina pinarensis cosdeni* Applin and Jordan, n. var. X22. Ventral view of holotype no. 559729. (p. 145)
9—*Quinqueloculina leoenensis* Applin and Jordan, n. sp. ×30. *a*, Side view of holotype no. 559702; *b*, ventral view of paratype no. 559703. (p. 136)
10—*Flintina avonparkensis* Applin and Jordan, n. sp. ×35. Holotype no. 559705. (p. 137)
11—*Spiroloculina seminolensis* Applin and Jordan, n. sp. ×30. *a*, Side view, *b*, edge view of holotype no. 559704. (p. 137)
12—*Fabularia gunteri* Applin and Jordan, n. sp., *a*, Side view, ×22; *b*, ventral view, ×36 of holotype no. 559706. (p. 137)

Applin and Jordan—Florida Foraminifera



Applin and Jordan—Florida Foraminifera

Globigerina cretacea? d'Orbigny.
Cushman Lab. Foram. Research Contr., vol. 18, pt. 3, p. 65, pl. 15, figs. 20–22, 1942.
Globotruncana arca (Cushman).
Jour. Paleontology, vol. 6, no. 4, pl. 51, figs. 13 a, b, 1932.
Globotruncana canaliculata (Reuss).
Idem, p. 343, pl. 51, figs. 14 a, b.
Gyroidina micheliniana (d'Orbigny).
Idem, p. 342, pl. 51, figs. 12 a, c.
Planulina cedarkeysensis Cole.
Florida Geol. Survey Bull. 20, pp. 35, 36, pl. 2, figs. 13, 14, 1942.
Planulina texana Cushman.
Cushman Lab. Foram. Research Contr., vol. 14, pt. 3, p. 69, pl. 12, fig. 3, 1938.
Stensioina americana Cushman and Dorsey.
Cushman Lab. Foram. Research Contr., vol. 16, pt. 1, pp. 5, 6, pl. 1, fig. 7, 1940.

SYSTEMATIC DESCRIPTIONS

Family LITUOLIDAE

Genus CRIBROSPIRA Muller, 1878

CRIBROSPIRA? BUSHNELLENSIS Applin and Jordan, n. sp.

Plate 18, figure 1

Haplophragmoides? bushnellensis, APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 4, fig. 7. (Nomen nudum.)

Test moderately large, subcircular in side view, compressed, nearly bilaterally symmetrical; umbilical area slightly depressed on both sides; usually completely involute, although rare specimens have last few chambers evolute; periphery narrowly rounded, somewhat lobulate; chambers simple, slightly inflated, numbering eight to ten in final coil; sutures broad, gently curved, depressed —a few specimens show series of short, regularly spaced projections extending forward at right angles along one side of suture lines; walls composed of very finely granular light-gray dolomite; aperture cribrate, consisting of series of small, irregularly spaced, slitlike openings on central portion of somewhat elongate apertural face.

Average diameter, 1.0 to 1.3 mm., average thickness, 0.37 mm.

All specimens studied are dolomitized and it is therefore not deemed advisable to make a more definite generic determination at this time.

Common at some levels in the Cedar Keys limestone (Paleocene) of peninsular Florida. Holotype from 2660 feet in the Pioneer Oil Co. Hecksher-Yarnell No. 1, "Kissengen Springs Well," Polk County, Florida.

Holotype U.S.N.M. no. 559689. Paratype U.S.N.M. no. 559689.

Genus CYCLAMMINA H. B. Brady, 1876

CYCLAMMINA WATERSI Applin and Jordan, n. sp.

Plate 18, figures 2a, b

Cyclammina watersi, APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 2, fig. 4. (Nomen nudum.)

Test usually circular in outline, occasionally somewhat distorted, laterally compressed, biumbilicate, involute; chambers inflated, numerous, averaging seven to nine in final whorl, last few chambers sometimes partially overlapping near umbilical area; periphery broadly rounded, lobulate; sutures gently curved, strongly depressed; walls thick, almost smooth with large amount of calcareous cement; chitinous in-

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EXPLANATION OF PLATE 19

FIGS. *1—Planispirina? kissengenensis* Applin and Jordan, n. sp. ×30. Holotype no. 559708. (p. 138)
2—Nonionella leonensis Applin and Jordan, n. sp. ×40. *a*, Dorsal view; *b*, apertural view; *c*, side view of holotype no. 55709. (p. 138)
3—Elphidium leonensis Applin and Jordan, n. sp. ×36. *a*, Dorsal view; *b*, apertural view of holotype, no. 559710. (p. 139)
4—Miscellanea nassauensis Applin and Jordan, n. sp. ×40. *a*, Side view; *b*, apertural view of holotype, no. 559713. (p. 139)
5—Eponides waltonensis Applin and Jordan, n. sp. ×69. *a*, Dorsal view of paratype no. 559718; *b*, ventral view, *c*, apertural view of holotype no. 559717. (p. 142)
6—Epistomaria semimarginata (d'Orbigny) ×40. *a*, Dorsal view, *b*, ventral view of plesiotype no. 559725, *c*, edge view of plesiotype no. 559726. (p. 144)
7—Globigerina velascoensis Cushman ×60. Dorsal view of plesiotype no. 559732 (p. 146)
8—Globorotalia velascoensis (Cushman) ×60. *a*, Dorsal view; *b*, ventral view of plesiotype no. 559734. (p. 146)
9—Cibicides harperi (Sandidge) ×40. *a*, Ventral view; *b*, dorsal view of plesiotype no. 103748; (p. 147)
10—Anomalina cosdeni Applin and Jordan, n. sp. *a*, Dorsal view of holotype no. 103746, ×40. *b*, ventral view ×50, *c*, edge view ×45, of paratype no. 103747. (p. 147)

ner lining present; aperture a very narrow curved slit at base of septal face, with numerous additional apertures above, on convex, coarsely cribrate plate which fits into narrow rim outlining apertural face.

Average diameter 0.8 to 1.0 mm., thickness 0.34 mm.

Common in the Avon Park limestone (late middle Eocene) of Florida.

Holotype from 190 feet in the U. S. Army, Kissimee Air Base Well, Osceola County, Florida. Fla. G. S. no. W-697.

Holotype U.S.N.M. no. 559690.

This species is named in honor of Mr. James A. Waters, of the Sun Oil Company who made many helpful suggestions in regard to the species described in this paper.

Family VALVULINIDAE
Genus VALVULINA d'Orbigny, 1826
VALVULINA AVONPARKENSIS Applin and Jordan, n. sp.
Plate 18, figure 3

Test slender, elongate; early portion triangular in outline; later portion, about three-fourths of test, cylindrical, almost uniform in diameter throughout; early chambers triserial, later chambers spirally coiled about elongate axis, several chambers to a coil; sutures depressed; chambers distinct, either gently inflated, or compressed; walls arenaceous, moderately smooth; aperture terminal, central, irregularly rounded to broadly elliptical in contour; small valvular tooth present.

Average diameter 0.4 to 0.45 mm., average length 1.5 mm.

This is possibly an ancestral form of *Clavulina corrugata* Deshayes, which is common in the Upper Eocene of France.

Common in the Avon Park limestone (late Middle Eocene) of Florida.

Holotype from 320 feet in the Florida Public Service Co., No. 1, West Robinson St., at Gas Plant, at Orlando, Orange County, Florida. Fla. G. S. no. W-527.

Holotype U.S.N.M. no. 559691.

VALVULINA INTERMEDIA Applin and Jordan, n. sp.
Plate 18, figure 4

Test free, conical in shape; early chambers triserial, later chambers arranged in elongate spiral forming about two-thirds of test, several chambers in a coil; sutures depressed; chambers distinct, inflated; walls finely arenaceous with large amount of calcareous cement; aperture terminal with large valvular tooth, which is broadened on mature specimens to form small, rounded, plate-like structure with series of small openings along edge.

Average diameter, 0.7 to 0.8 mm., average length, 1.5 to 1.7 mm.

This species is closely related to *Cribobulimina cushmani* and apparently represents a transitional form in which the typical apertural characteristics of *Valvulina* are changing and approaching the stage found in the typical *Cribobulimina*.

Abundant in the Avon Park limestone (late Middle Eocene) of Florida.

Holotype from 320 feet in Florida Public Service Co. No. 1, West Robinson St., at the gas plant, Orlando, Orange County, Florida. Fla. G. S. no. W-527. Holotype U.S.N.M. no. 559692.

Genus CRIBROBULIMINA Cushman, 1927
CRIBROBULIMINA CUSHMANI Applin and Jordan, n. sp.
Plate 18, figures 5a, b

Valvulina cushmani, APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 2, figs. 6, 7. (Nomen nudum.)

Test broadly conical in outline; early chambers triserial, later chambers in loose, elongate spiral, several chambers to a coil; chambers distinct, inflated; sutures strongly depressed; walls finely arenaceous, smoothly finished; aperture in mature forms covered by convex, circular, cribrate plate; in younger forms plate not cribrate, but with series of small openings along edge.

Average diameter, 0.8 to 0.9 mm., average length, 1.5 to 1.7 mm.

Abundant in the Avon Park limestone (late Middle Eocene) of Florida.

Types from 460 feet in R. O. Couch Well, Brevard County, Florida. Fla. G. S. no. W-104.

Holotype U.S.N.M. no. 559694. Paratype U.S.N.M. no. 559693.

This species is named in honor of Dr. Joseph A. Cushman.

Genus VALVULAMMINA Cushman, 1933
VALVULAMMINA MINUTA Applin and Jordan, n. sp.
Plate 18, figures 6a–c

Test small, globigerinoid; periphery broadly rounded; spire very low; final whorl forming about three-fourths of test; chambers in last whorl distinct, inflated, about seven in number; sutures strongly depressed; chambers in earlier whorls usually indistinct with sutures slightly, if at all depressed; walls moderately smooth, with large amount of calcareous cement; aperture a low, arched opening near umbilicus on ventral side of last-formed chamber from which broad, flat valvular tooth extends outward almost covering umbilical area.

Average diameter 0.4 to 0.5 mm., average height 0.28 mm.

Common in the Avon Park limestone (late Middle Eocene) of Florida.

Types from 320 feet in Florida Public Service Company, No. 1, West Robinson St. at Gas Plant, Orlando, Orange County, Florida. Fla. G. S. no. W-527.

Holotype U.S.N.M. no. 559695. Paratype U.S.N.M. no. 559696.

VALVULAMMINA NASSAUENSIS Applin and Jordan, n. sp.
Plate 18, figures 7a, b

Test subglobular, trochoid; periphery broadly rounded; spire on some specimens compressed, on others low conical in contour; final whorl forming about two-thirds of surface of test; chambers distinct, gently inflated, increasing rapidly in breadth, remaining about uniform in height as added in last coil which consists of 7 to 9 chambers; sutures depressed; walls moderately smooth, usually composed mainly of finely granular dolomite; aperture moderately large with valvular tooth.

Diameter 0.7 mm., average height 0.52 mm.

Cedar Keys limestone (Paleocene) of Florida. This form often occurs at, or very close to the top of the formation. It is frequently found some distance above the point in the section where abundant specimens of the characteristic *Borelis* species last appear.

Types from 2215 feet in the St. Marys River Oil Corp. Hilliard Turpentine Co., No. 1, Nassau County, Florida.

Holotype U.S.N.M. no. 559697. Paratype U.S.N.M. no. 559698.

Genus MARSSONELLA Cushman, 1933
MARSSONELLA OXYCONA FLORIDANA Applin and Jordan, n. var.

Gaudryina trochoides, WHITE, 1928, Jour. Paleontology, vol. 2, no. 4, p. 314, pl. 42, fig. 11.
Gaudryina oxycona, CUSHMAN and JARVIS, 1932, U. S. Nat. Mus. Proc., vol. 80, art. 14, p. 18, pl. 5, fig. 1 (not 2).
Marssonella oxycona, CUSHMAN, 1937, Cushman Lab. Foram. Research Spec. Pub. 8, pl. 6, fig. 9a.

Test small, conical in shape, tapering rapidly from subacute initial end; early chambers triserial, adult chambers biserial; chambers distinct, not inflated, increasing rather rapidly in size as added; sutures very broad, distinctly marked, either flush or slightly raised above surface; walls very finely arenaceous, smoothly finished; aperture a broad, slit-like opening at inner margin of last formed chamber, centrally enlarged by a small, circular indentation.

Greatest diameter 0.50 mm., average height 0.60 mm.

From the literature the species would seem to be a quite variable form, but the specimens studied from the Florida Paleocene are constant in their characteristics, and seem to be closely related only to the form figured by Cushman from beds of presumably the same age in Trinidad, and reported by him and by White from the Velasco shales of Mexico.

Beds of Tamesí (Velasco) age (Paleocene) of western Florida.

Holotype from core, 3055–61 feet in the Oil City Corp., Walton Land and Timber Company, No. 1, Walton County, Florida.

Holotype U.S.N.M. no. 559699.

Genus DICTYOCONUS Blanckenhorn, 1900
DICTYOCONUS COOKEI (Moberg)
Text figure 1

Coskinclina cookei MOBERG, 1928, Florida Geol. Survey 19th Ann. Rept., pp. 166–68, pl. 3, figs. 1–5, 7–8 (not fig. 6).
Dictyoconus cookei (Moberg) COLE, 1941, Florida Geol. Survey Bull. 19, pp. 26, 27, pl. 3, figs. 11–13; pl. 5, figs. 6–10, 12, 13; pl. 6, figs. 1–8; pl. 18, fig. 12.—COLE, 1942, Florida Geol. Survey Bull. 20, pp. 24, 25, pl. 3, fig. 10, pl. 4, fig. 8.

Dictyoconus cookei is sometimes much smaller, and more sharply conical in outline than average specimens of *D. americanus*, but, on the other hand, these two species are often practically identical in outward appearance. The cellule shape and pattern of these forms, however, is quite distinct, and on this basis, the species can be easily recognized. A detail of the eroded surface of *D. cookei* and of *D. americanus* is given to illustrate this difference in their structural features.

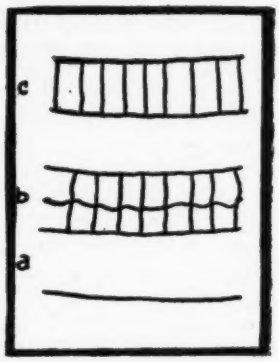

FIG. 1—*Dictyoconus cookei* (Moberg). *a*. Smooth outer shell layer. *b*. Division of chamberlets in layer just below *a*. *c*. Chamberlets below *b*. Magnified approx. ×85.

D. cookei is found in the Avon Park limestone (late Middle Eocene) and the Suwannee limestone (Oligocene) of Florida.

DICTYOCONUS AMERICANUS (Cushman)
Plate 20, figure 1; plate 21, figure 1; text figure 2

Conulites americana CUSHMAN, 1919, Carnegie Inst. Washington Publ. 291, p. 43. text-fig. 3.

Dictyoconus americana, SILVESTRI, 1925, Acad. Lincei Mem., ser. 2, vol. 8, p. 52.—VAUGHAN, 1932, Jour. Paleontology, vol. 6, p. 95, pl. 14, figs. 3–5.—CUSHMAN, 1937, Cushman Lab. Foram. Res. Spec. Pub. 8, p. 189, pl. 23, figs. 6–9.—COLE, 1942, Florida Geol. Survey Bull. 20, pp. 21–24, pl. 3, figs. 12, 13; pl. 6, figs, 1–9; pl. 7, figs. 1–5; pl. 16, figs. 14, 15.—COLE, 1944, Florida Geol. Survey Bull. 26, pp. 36, 37, pl. 4, figs. 1–6; pl. 8, figs. 12, 13; pl. 18, fig. 11.

Dictyoconus codon WOODRING, 1924, Geol. Repub. Haiti, p. 608, pl. 9, figs. 1, 2.—VAUGHAN, 1928, Jour. Paleontology, vol. 1, p. 280, pl. 43, figs. 1–5.—VAUGHAN, 1932, Jour. Paleontology, vol. 6, p. 97, pl. 14, figs. 1–2.—CUSHMAN, 1937, Cushman Lab. Foram. Res. Spec. Pub. 8, p. 190, pl. 23, figs. 6–9.—COLE, 1941, Florida Geol. Survey Bull. 19, p. 28, pl. 7, figs. 1, 7; pl. 18, figs. 10, 11.

Dictyoconus? gunteri MOBERG, 1928, Florida Geol. Survey 19th Ann. Rept., p. 168, pl. 3, figs. 9, 10; pl. 4, figs. 1–3.—CUSHMAN, 1937, Cushman Lab. Foram. Res. Spec. Pub. 8, p. 191, pl. 24, figs. 1–3.—COLE, 1941, Florida Geol. Survey Bull. 19, pp. 27, 28, pl. 3, figs. 8–10; pl. 7, figs. 2–6, 8.

Dictyoconus puilboreauensis WOODRING, 1924, Geol. Repub. Haiti, p. 609, pl. 9, figs. 3, 4, 7, 8.—VAUGHAN, 1928, Jour. Paleontology, vol. 1, p. 281, pl. 43, fig. 6.—DAVIES, 1930, Royal Soc. Edinburgh Trans., vol. 56, p. 504, pl. 56, fig. 12.

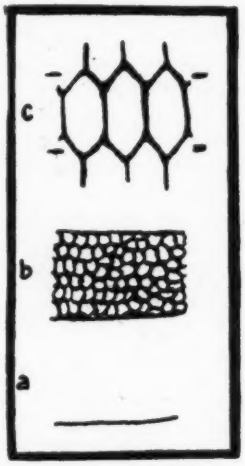

FIG. 2—*Dictyoconus americanus* (Cushman). *a*. Smooth outer shell layer. *b*. Cellules just below *a*. *c*. Chamberlets in layer below *b*. Magnified approx. ×85.

A detail of the eroded surface, showing the intricate, lacy pattern of the cellules is given in text figure 2 for comparison with the cellule pattern of *D. cookei*.

This form is one of the most characteristic markers for the Lake City limestone (early Middle Eocene) of Florida.

Plesiotypes U.S.N.M. nos. 559700, 559-701.

Family MILIOLIDAE
Genus QUINQUELOCULINA d'Orbigny, 1826
QUINQUELOCULINA LEONENSIS Applin and Jordan, n. sp.
Plate 18, figures 9a, b

Quinqueloculina leonensis APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 1, fig. 2. (Nomen nudum.)

Test broadly oval in front view, somewhat compressed; periphery subacute; test, on side showing four chambers, sloping rather steeply from center to periphery; opposite side flat to gently convex, three chambers visible; chambers broadly curved, subacute at periphery, of almost uniform width throughout; sutures distinct, shallow; final chambers slightly overlapping earlier chambers along suture lines; apertural end extended very little beyond outline of test; aperture rounded, with small lip; walls dull, on well preserved forms finely papillate; angular character of periphery of chambers shown only on rare, well preserved specimens.

Average length 1.10 mm., average width 1.00 mm., thickness 0.70 mm.

Suwannee limestone (Oligocene) of Florida.

Types from 230 feet in Federal Correctional Inst. Well, Leon County, Florida. Fla. G. S. no. W-350.

Holotype U.S.N.M. no. 559702. Paratype U.S.N.M. no. 559703.

Genus SPIROLOCULINA d'Orbigny, 1826

SPIROLOCULINA SEMINOLENSIS Applin and Jordan n. sp.

Plate 18, figures 11a, b

Spiroloculina seminolensis APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 2, figs. 1a, b. (Nomen nudum.)

Test broadly elliptical in outline, slightly longer than broad, much compressed, central area somewhat depressed; outer margin gently convex, tricostate, costae evenly spaced, so arranged as to give test in side view truncated appearance along periphery; inner margin of final chambers overlapping earlier chambers, meeting near center of test in shallow, somewhat irregular usually obscure suture line; walls smooth, not porcelanous; apertural end somewhat extended; aperture rounded with small lip.

Length 1.0 mm., greatest breadth 0.8 mm., thickness 0.23 mm.

Lower member of the Ocala limestone (upper Eocene) Florida.

Holotype from 153–55 feet in Frank L. Woodruff Well, 9 miles west of Lake Monroe, Seminole County, Florida. Fla. G. S. no. W-337.

Holotype U.S.N.M. no. 559704.

Genus FLINTINA Cushman, 1921

FLINTINA AVONPARKENSIS Applin and Jordan, n. sp.

Plate 18, figure 10

Flintina avonparkensis APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 2, fig. 5. (Nomen nudum.)

Test compressed, central area strongly concave on both sides; periphery, on well preserved forms, squarely truncate, strongly lobulate, bordered on each side by well defined rib from which chamber walls slope steeply upward to central area marked either by a third costa, or by narrow flattened ridge; chambers in early stages quinquelocular, final chambers in single plane, four or five commonly present in last coil; sutures distinct, strongly depressed; walls on well preserved specimens ornamented by numerous, fine, longitudinal striations; aperture circular, on short neck, with distinct, flaring lip and small bifid tooth.

Average length 1.5 mm., breadth 1.2 to 1.5 mm., thickness 0.40 mm.

Avon Park limestone (late Middle Eocene) of Florida.

Types from 440–530 feet in International Fruit Corp. Well No. 1, at Lucerne park, Polk County, Florida, Fla. G. S. no. W-616.

Holotype, U.S.N.M. no. 559705. Paratype, U.S.N.M. no. 559705.

Genus FABULARIA Defrance, 1820

FABULARIA GUNTERI Applin and Jordan, n. sp.

Plate 18, figures 12a, b

Test nearly oval in front view, somewhat compressed in side view, biconvex, slightly longer than broad; periphery narrowly to broadly rounded; early chambers quinqueloculine, later chambers biloculine, added on alternate sides of test in planes 180 degrees apart, involute; sutures distinct, depressed; walls ornamented with very fine longitudinal striae, also marked by wide, light colored lines which are outer reflections of costae dividing chambers internally into series of meridionally running canals, or chamberlets; aperture a large terminal opening, elliptical to oval in outline, surrounded by row of small openings, on well preserved specimens bordered above by slightly pro-

jecting lip. Transverse sections of mature forms show average of 12 to 14 bilocular chambers with about 18 to 20 chamberlets in final chamber; chamber walls moderately thick, about equal in width throughout biloculine stages of growth.

Average length 1.60 to 1.80 mm., width 1.20 to 1.40 mm., thickness 0.76 mm.

This species is similar to *Fabularia howchini* Schlumberger[1] which was described from the Miocene of Australia. The Florida form is not as strongly compressed, the surface is finely striate, the chamber walls are thinner and the chamberlets apparently more numerous and more regular in contour.

F. gunteri, although sometimes occurring alone, often appears in well sections accompanied by many specimens of *F. vaughani* Cole and Ponton.[2] It can be distinguished easily from the latter species by the position of the suture and the character of the ornamentation and aperture. On *F. vaughani* the suture line separating the chambers follows a longitudinally diagonal course across the central portion of the flattened sides of the test, while in *F. gunteri* it outlines the rim of the test, giving the form the outward appearance of *Pyrgo*. In *F. gunteri* the surface is finely striate, and the inner costae are broad, fairly even and continuous, while the surface of *F. vaughani* is described as "ornamented by rather heavy costae which are discontinuous. The various portions of the costa are slightly offset one to the other at the breaks." The aperture on *F. gunteri* is well defined and distinctive; on *F. vaughani* it is obscure. The two species differ also in their general outlines, since *F. gunteri* is broadly oval, while *F. vaughani* is compressed spindle-shape. There is an apparent difference in the stratigraphic ranges of these species. *F. gunteri* has been found only in the Lake City limestone (early middle Eocene) but *F. vaughani*[3] has also been reported from the Avon Park limestone (late middle Eocene).

Lake City limestone (early Middle Eocene) of Florida.

Holotype from 508–515 feet in the City of Lake City Well No. 1, Columbia County, Fla. Fla. G. S. no. W-299.

Holotype U.S.N.M. no. 559706.

This species is named in honor of Dr. Herman Gunter, director of the Florida Geological Survey.

[1] Schlumberger, C., 1891, Royal Soc. Southern Australia Trans., pp. 347–349, text figs. 1–4.

[2] Cole and Ponton, 1934, Amer. Midland Nat., vol. 14, pp. 139–141, pl. 1, figs. 1–9.

[3] Cole, W. Storrs, 1942, Florida Geol. Survey Bull. 20, p. 25.

Family Ophthalmididae

Genus Planispirina Sequenza, 1880

Planispirina? kissengenensis Applin and Jordan, n. sp.

Plate 19, figure 1

Test nautiloid, somewhat concave in central area on both sides, completely involute; periphery rounded, irregularly circular in outline, slightly lobulate; walls thick, white, surface waxy in appearance; adult whorl composed of about six involute chambers, not sharply defined on exterior of test, poorly shown on interior of all specimens studied; chambers apparently present only in later coils; about four and one half coils usually present; sutures not distinctly marked; aperture simple, formed by open end of last chamber.

Average diameter 0.75 mm., thickness 0.44 mm.

This species does not conform perfectly with the generic description of *Planispirina* since it is completely involute. Also, the interiors of all specimens studied were altered by calcite replacement which made it impossible to secure satisfactory sections. The form is therefore questionably referred in this genus.

Abundant at some levels in the Cedar Keys limestone (Paleocene) of Florida.

Holotype from 3370 feet in the Pioneer Oil Co., Hecksher-Yarnell No. 1 "Kissengen Springs Well," Polk County, Florida.

Holotype, U.S.N.M. no. 559708.

Family Nonionidae

Genus Nonionella Cushman, 1926

Nonionella leonensis Applin and Jordan, n. sp.

Plate 19, figures 2a–c

Test moderately large, asymmetrical, strongly compressed; periphery subacute; dorsal side with small portion of early whorls visible, ventral side involute; chambers not inflated, numerous, increasing rather rapidly in breadth as added, about 12 present in last coil of adult forms; final chamber on ventral

side extended into umbilical area; suture lines distinct, slightly depressed, gently, evenly curved; walls smooth; apertural face slightly convex, narrowly elliptical in outline; aperture a low opening along base of final chamber.

Average length 0.70 mm., breadth 0.50 mm., thickness 0.12 mm.

Suwanee limestone (Oligocene) of Florida.

Holotype from 440–470 feet in C. Poucher Well, Hardee County, Florida. Fla. G. S. no. W-592.

Holotype, U.S.N.M. no. 559709.

Genus ELPHIDIUM Montfort, 1808

ELPHIDIUM LEONENSIS Applin and Jordan, n. sp.

Plate 19, figures 3a, b

Test of medium size, closely coiled, completely involute, somewhat compressed; periphery narrrowly rounded; sides gently convex in peripheral view; umbilical region flattened, or slightly concave, covered by group of small nodes which often merge to form a low boss; chambers distinct, slightly, if at all inflated, of nearly uniform height throughout, 14 to 16 usually present in final coil of adult forms; sutures slightly depressed, very gently curved, marked by numerous, short retral processes; walls smooth, polished on unaltered specimens; aperture a small, narrow opening at base of semielliptical apertural face.

Average diameter 0.50 to 0.70 mm., thickness 0.21 mm.

Suwanee limestone (Oligocene) of Florida.

Holotype from 240 feet in Federal Correctional Inst. Well No. 1, Leon County, Florida. Fla. G. S. no. W-350.

Holotype, U.S.N.M. no. 559710.

Family CAMERINIDAE

Subfamily CAMERININAE

Genus CAMERINA Brugière, 1792

CAMERINA aff. C. VANDERSTOKI (Rutten and Vermunt)

Plate 20, figures 3a, b

Nummulites vanderstoki RUTTEN and VERMUNT, 1932, K. Akad. Wetensch. Proc., vol. 35, p. 240, fig. 8, pl. 2, figs. 6, 12.

Camerina vanderstoki, BARKER, 1939, U. S. Nat. Mus. Proc., vol. 86, no. 3052, pp. 322, 323, pl. 13, fig. 7; pl. 18, fig. 3; pl. 22, figs. 10–12.—COLE, 1941, Florida Geol. Survey Bull. 19, pp. 28, 29, pl. 8, figs. 2–10.—COLE, 1942, Florida Geol. Survey Bull. 20, pp. 27, 28, pl. 3, fig. 8; pl. 8, figs. 1, 2, 9, 10.

Camerina aff. *C. vanderstoki* APPLIN and APPLIN 1944, Am. Association Petroleum Geol. Bull., vol. 28, 12, pl. 1, fig. 8.

The lower member of the Ocala limestone generally contains few, if any, specimens of the forms which are usually referred to as "larger Foraminifera." However, in several wells drilled in areas where the upper member of the Ocala is missing specimens of *Camerina* aff. *C. vanderstoki* are fairly common in samples taken through the lower member. This form, although similar to *C. vanderstoki* in many respects, seems to show certain constant differences. The Florida forms are not as compressed, the thickness through the center is greater, and the umbonal areas are covered on each side by a distinct boss, from which broad, raised septa descend in a gentle curve toward the periphery. The septa are strongly recurved near the rim of the test, and generally narrow abruptly at a point about midway between the umbo and the periphery. In horizontal section the Florida forms are very similar to the figures given for the type of the species.

Average diameter 2.40 to 2.50 mm., average thickness 1.10 mm.

Lower member of the Ocala limestone (upper Eocene) of Florida, Cole[4] reports a form, which is presumably the same, from the upper member of the Ocala, also.

Plesiotypes from 40 and 45 feet in the Auxiliary Training Field Well, at Montbrook, southwest of Williston, Levy County, Florida. Fla. G. S. no. W-652.

Plesiotypes, U.S.N.M. no 559711, 559712.

Genus MISCELLANEA Pfender, 1934

MISCELLANEA NASSAUENSIS Applin and Jordan, n. sp.

Plate 19, figures 4a, b

Miscellanea sp. APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 4, fig. 1a, b.

Test moderately small, subcircular in side view, equally biconvex, almost entirely involute, last few chambers not completely embracing; peripheral margin narrowly to broadly rounded; only last few chambers

[4] Cole, W. Storrs, 1942, Fla. Geol. Sur. Bull., no. 20, p. 28, pl. 8, figs. 1, 2.

visible at surface, these chambers gently inflated, slightly lobulate at periphery, separated by shallow sutural depressions; exterior completely covered with small pustules usually largest over center of test where they sometimes coalesce to form low, short, irregular, diverging ridges; aperture obscure, apparently a narrow opening at base of septal face on periphery. Median sections show an average of three to three and one half volutions, with about 26 chambers commonly present in final coil; chambers uniform in shape, length about twice width in last convolution; chamber walls gently curved; spiral lamina forming outer wall of chambers in penultimate whorl very thick, slightly broader than chambers which it borders; canal system typically developed; vertical sections show supplementary skeleton to be composed of a fine, closely packed series of radiating pillars.

Average diameter 1.20 mm., average thickness 0.84 mm.

This very distinctive species is often abundant in the lower portion of the Oldsmar limestone (Lower Eocene) of peninsular Florida.

Holotype from 2015 feet in the St. Marys River Oil Corp., Hilliard Turpentine Company, No. 1, Nassau County, Florida.

Holotype, U.S.N.M. no. 559713.

MISCELLANEA NASSAUENSIS RETICULOSUS
Applin and Jordan, n. var.

This variety occurs with typical specimens in some well sections, but in others, either the species or the variety appears alone, and generally dominates the fauna. The variety differs in surface ornamentation, only. The exterior of the test is finely reticulate, being completely covered with a mesh-like arrangement of narrow, slightly raised lines.

Lower portion of the Oldsmar limestone (Lower Eocene) of Florida.

Holotype from 1545 feet in Suwannee Petrol. Corp. Sholtz No. 1, Levy County, Florida.

Holotype, U.S.N.M. no. 559714.

Family CAMERINIDAE
Genus OPERCULINA d'Orbigny, 1826
Subgenus SULCOPERCULINA Thalman, 1938
OPERCULINA (SULCOPERCULINA) COSDENI Applin and Jordan, n. sp.
Plate 20, figures 2a–c

Miscellanea dickersoni, COLE. 1944, Florida Geol. Survey Bull. 26, pp. 38, 39, pl. 21, figs. 8–11.
Sulcoperculina cosdeni APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 5, fig. 5.

Test thickly lenticular, usually completely involute, generally strongly umbonate, bilaterally symmetrical to slightly asymmetrical; last few chambers of microspheric specimens sometimes flattened near periphery, final chambers of megalospheric forms not always completely embracing; sutures fairly distinct, flush with surface, radial to point near periphery where they abruptly recurve to unite with preceding suture forming intramarginal, lobulate band; umbonal area on each side covered by large boss with deeply pitted appearance on well preserved specimens; surface of test near umbos somewhat granular; periphery bordered on each side by broad row of very small, closely packed, radial plates giving edge of test characteristic fringed appearance; a shallow depression, or canal, encircles rim of test between dorsal and ventral rows of plates which generally cover it, clearly visible only on broken or worn specimens; chambers uniform in shape throughout, increasing very slowly in size as added, average of 12 to 16 present in final coil; three to three and one half coils usually present in

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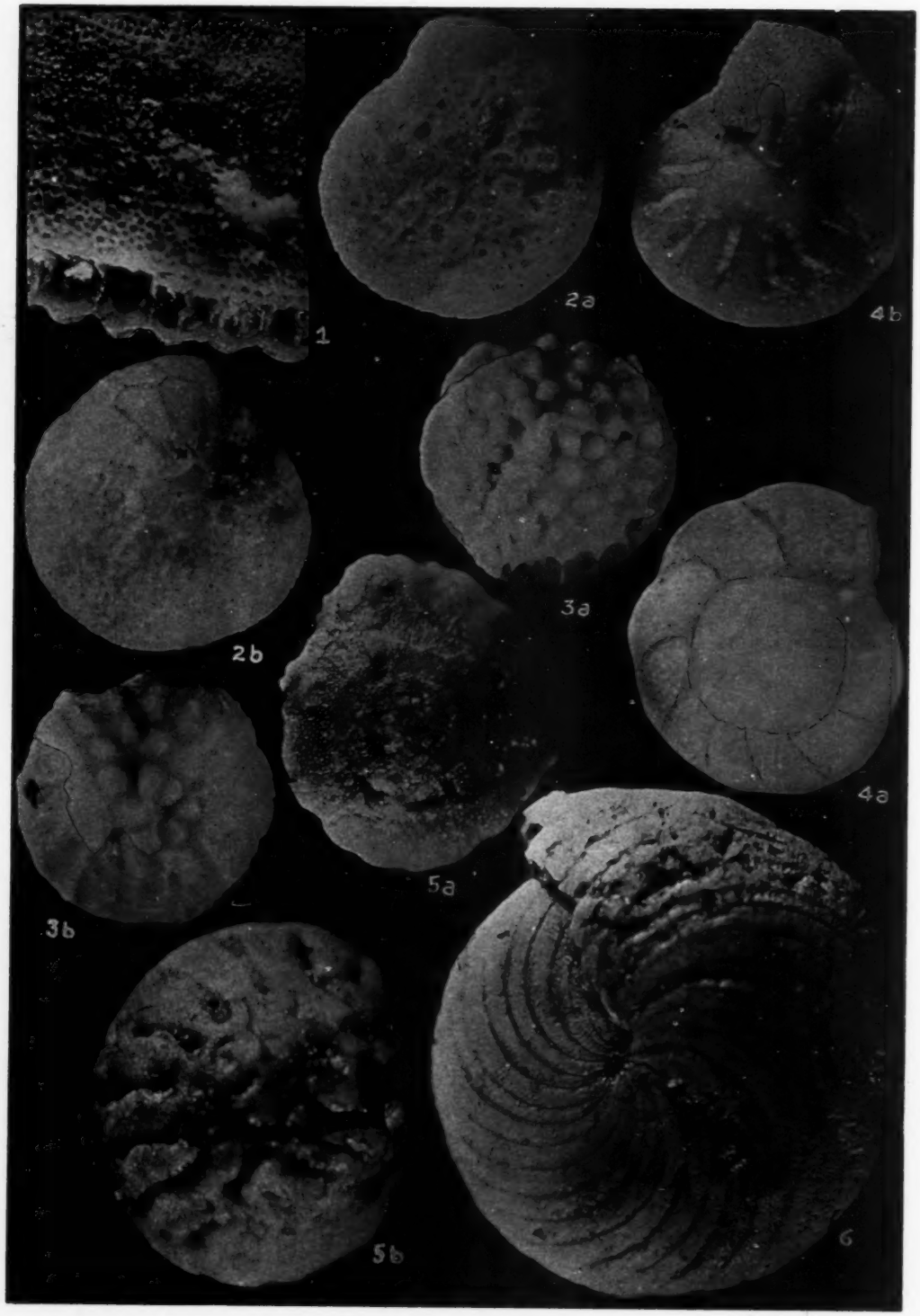
EXPLANATION OF PLATE 20

FIGS. *1—Dictyoconus americanus* (Cushman). ×30. Detail of cellule pattern. Plesiotype no. 559701. Plesiotype no. A. (p. 136)
2—Operculina (Sulcoperculina) cosdeni Applin and Jordan, n. sp. ×30. *a* and *b*, Opposite sides of holotype no. 103744; *c*, edge view of paratype no. 103745. (p. 140)
3—Camerina aff. *C. vanderstoki* (Rutten and Vermunt). ×15. *a*, Equatorial section of split specimen; *b*, surface view, plesiotypes no. 559711, 559712. (p. 139)
4—Anomalina rubiginosa Cushman. ×40. Dorsal view. Plesiotype no. 559735. (p. 147)
5—Planulina waltonensis Applin and Jordan, n. sp. ×60. *a*, Dorsal view; *b*, ventral view; *c*, edge view of holotype no. 559736. (p. 147)

Applin and Jordan—Florida Foraminifera



Applin and Jordan—Florida Foraminifera

mature forms; aperture a small curved opening at base of septal face on periphery. Transverse sections show thick septal walls with clearly defined canal system; small openings apparent near proximal ends of radial septa.

Average diameter 1.35–1.50 mm., average thickness 0.61 mm.

This species is similar in some respects to *Camerina? dickersoni* D. K. Palmer,[5] which was described from the Cuban Cretaceous; and it also may be related to the form referred to that species by Barker[6] from the Cardenas beds of Mexico. However, topotypes of *C. dickersoni* were compared with a series of about fifty specimens of *S. cosdeni* chosen from well sections located in various parts of the Florida peninsula from Monroe Co., into Nassau County, and the two species were found to differ consistently in several respects. The Florida species is stoutly lenticular, not thin and compressed; the sutures are fairly distinct, but not raised; the chambers are generally less numerous; the central area is strongly elevated, while on the Cuban form it is generally depressed; the umbos are very large, pitted and bordered by a granular area, whereas on *C.? dickersoni* they are small to moderately large, smooth, flattened, and granulations are not present. On this basis the Florida form is described as a new species.

The Florida species seems to conform to the requirements of the subgenus *Sulcoperculina* since there is a peripheral canal, a marginal fringe of fine plates, and the septa show a tendency to break up into pillars in the umbonal area only.

The specimens found in the Nassau County well, and figured by Cole in the reference given in the synonomy are exceptionally small, poorly developed forms. They represent the most northern known occurrence of the species.

Abundant and highly characteristic of the lower member of the Lawson limestone (Upper Cretaceous) of Florida.

Types from 2560 feet in J. S. Cosden, W. L. Lawson No. 1, Marion County, Florida.

Holotype, U.S.N.M. no. 103744. Paratype, U.S.N.M. no. 103745.

[5] Palmer, D. K., 1934, Soc. cubana hist. nat. mem., vol. 8, p. 243, figs. 4, 5, pl. 14, figs. 1, 2, 4, 6, 8.
[6] Barker, R. Wright, 1940, U. S. Nat. Mus. Proc., vol. 86, pp. 326, 327, pl. 20, fig. 3, pl. 21, fig. 12.

Family PENEROPLIDAE
Genus ARCHAIAS Montfort, 1808
ARCHAIAS COLUMBIENSIS Applin and Jordan, n. sp.
Plate 21, figure 6

Archaias columbiaensis APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 3, fig. 10. (Nomen nudum.)

Tests compressed, lenticular, bilaterally symmetrical, closely coiled, almost completely involute except for chambers of last half of final coil which are not completely embracing; periphery subacute; chambers very short, numerous, averaging 22 in final coil of adult specimens; sutures slightly depressed, strongly recurved; walls very finely striate; aperture either broken or obscure on all specimens studied, apparently a single row of closely spaced pores on narrow apertural face of final chamber.

Diameter 2.30 mm., thickness 0.69 mm.

At least two species of *Archaias* are present in the upper portion of the Lake City limestone. The writers have described the form which they believe to be the most common and most widely distributed. This occurrence extends the downward range of the genus which has not been previously reported from beds older than the Oligocene.

EXPLANATION OF PLATE 21

FIGS. *1—Dictyoconus americanus* Cushman. ×30. Detail of cellules with outer surface removed. Plesiotype no. 559700. (p. 136)
2—Amphistegina nassauensis Applin and Jordan, n. sp. ×40. *a*, Dorsal view; *b*, ventral view of holotype no. 559731. (p. 145)
3—Amphistegina alabamensis Applin and Jordan, n. sp. ×35. *a*, Dorsal view; *b*, ventral view of holotype no. 559728. (p. 145)
4—Rotalia avonparkensis Applin and Jordan, n. sp. ×80. *a*, Ventral view; *b*, dorsal view of holotype no. 559719. (p. 142)
5—Lockhartia cushmani Applin and Jordan, n. sp. ×30. *a*, Dorsal view of holotype no. 559723; *b*, ventral view of paratype no. 559724. (p. 143)
6—Archaias columbiensis Applin and Jordan, n. sp. ×15. Holotype no. 559715. (p. 141)

Lake City limestone (early Middle Eocene) of Florida.

Types from 499–505 feet and 610 feet in the City of Lake City well, Columbia County, Florida. Fla. G. S. no. W-299.

Holotype, U.S.N.M. no. 559715. Paratype, U.S.N.M. no. 559716.

Family ROTALIIDAE
Genus EPONIDES Montfort 1808
EPONIDES WALTONENSIS Applin and Jordan, n. sp.
Plate 19, figures 5a–c

Test usually almost equally and gently biconvex, some specimens strongly convex dorsally, gently convex ventrally; all coils visible on dorsal face, with about three and one half coils present in mature forms; periphery acute, slightly keeled; sutures distinct, not raised, gently curved; chambers numerous, 10 to 12 usually present in final coil, not inflated, increasing very gradually in size as added; walls very finely perforate; umbilical area filled with low boss; aperture narrow, elongate, extending from umbilicus to point just ventral to periphery, where it broadens into low arch.

Diameter 0.50 mm., average thickness 0.17 mm.

Common in the beds of Tamesí (Velasco) age (Paleocene) of northwestern Florida.

Type from core, 3055–3061 feet in the Oil City Corporation's Walton Land and Timber Co. No. 1, Walton County, Florida.

Holotype, U.S.N.M. no. 559717. Paratype, U.S.N.M. no. 559718.

Genus ROTALIA Lamarck, 1804
ROTALIA AVONPARKENSIS Applin and Jordan, n. sp.
Plate 21, figures 4a, b

Test unequally biconvex, usually moderately convex dorsally, slightly convex to almost flat ventrally; periphery acute, forming narrow keel seen on some specimens; slightly lobulate; chambers 7 to 9 in adult coil, increasing very gradually in size as added; about two and one half coils shown on dorsal face, chambers in early coils obscure; chamber walls on dorsal face flat, on ventral face, slightly inflated; sutures on dorsal face, limbate, flush with surface, gently curved; on ventral face, almost radiate, deeply channeled, broadening rapidly near periphery; walls finely perforate; umbilical area sometimes with plug, more commonly covered by inner ends of chambers which may overlap slightly; aperture an elongate opening on inner margin of ventral side of final chamber.

Diameter 0.60 to 0.70 mm., average thickness 0.13 mm.

Avon Park limestone (late Middle Eocene) of Florida.

Holotype from 145 feet U. S. Army, Kissimmee Airfield Well No. 1, Osceola County, Florida. Fla. G. S. no. W-696.

Holotype, U.S.N.M. no. 559719.

ROTALIA BYRAMENSIS Cushman

Rotalia byramensis CUSHMAN, 1922, U. S. Geol. Survey Prof. Paper 129E, p. 99, pl. 23, fig. 1.—CUSHMAN and MCGLAMERY, 1938, U. S. Geol. Survey Prof. Paper 189D, p. 110, pl. 27, fig. 3.—GALLOWAY and HEMINWAY, 1941, New York Acad. Sci., vol. 3, pt. 4, pp. 378–9, pl. 19, fig. 1a–c.—APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 1, figs. 1a, b.

This species is an abundant and highly characteristic fossil in the Suwannee limestone (Oligocene) of Florida. A rather wide variation in the shape and ornamentation of the specimens was noted at different localities. The extremes of variation are represented, on the one hand, by a strongly compressed, smooth form, on which the peripheral ends of the chambers in the final coil are V-shaped and terminate in short, spine-like processes; while the opposite extreme was shown by specimens which are relatively thick, with rounded, slightly lobulate peripheries, having the surface on the dorsal face ornamented with fine granules and with the ventral face strongly papillate. Gradations between these two extremes were found at various localities. In some wells, mainly in north-central Florida and southern Georgia, *Rotalia mexicana* Nuttall and its variety *R. mexicana mecatepenensis* Nuttall takes the place of *R. byramensis* in the fauna.

This species was described from the Byram marl of Mississippi where it was reported as not common. It is also reported from the Mint Springs marl member of the Oligocene, and good specimens were obtained at Choctaw Bluff, Clark County, Alabama, from the Chickasawhay marl member of the Byram marl. The species is also re-

corded from the Ponce formation, Oligocene, of Puerto Rico. It is common in the Suwannee limestone (Oligocene) of Florida.

Plesiotype from 230 feet in the Federal Correctional Inst. Well No. 1, Leon County, Florida. Fla. G. S. no. W-350 (figures in Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 1, fig. 1a, b).

Plesiotype, U.S.N.M. no. 559720.

ROTALIA CUSHMANI Applin and Jordan, n. sp.

Rotalia sp. CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 46, pl. 19, fig. 11a, c.

Test planoconvex, dorsal face raised in high conical spire, ventral face almost flat; periphery subacute, bluntly keeled; chambers of early whorls not clearly shown, 8 to 10 in adult whorl, increasing very slowly in size as added; sutures on dorsal side moderately curved, broad, thick, slightly elevated above surface of test; walls finely perforate, thin, commonly broken and missing in chambers of the final whorl as shown in Cushman's figure; sutures on ventral side radial, incised; umbilicus filled with low boss; aperture an irregularly curved, narrow opening on ventral face, extending from umbilicus to periphery along inner margin of last chamber.

Average diameter 0.70 to 1.0 mm., height 0.23 mm.

This species is occasionally found in the upper member of the Ocala limestone (Upper Eocene) but it is common to abundant in the lower member, where it is the dominant rotaliid in the fauna, as *Eponides jacksonensis* (Cushman and Applin) is dominant in the upper member.

Types from 195–200 feet U. S. Army Air Base, two miles east of Orlando, Orange County, Florida. Fla. G. S. no. W-601.

Holotype, U.S.N.M. no. 559721. Paratype, U.S.N.M. no. 559722.

This species is named in honor of Dr. Joseph A. Cushman, who first figured the form in the reference given in the synonomy.

GENUS LOCKHARTIA Davies, 1932

LOCKHARTIA CUSHMANI Applin and Jordan, n. sp.

Plate 21, figures 5a, b

Truncatulina sp. CUSHMAN, 1921, Florida Geol. Survey, 13th Ann. Rept., p. 52, pl. 3, figs. 1a, b.

Lockhartia? sp., APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 3, figs. 1a, b; 2.

Test moderately large, unequally biconvex, dorsal face slightly convex to low convex, ventral face usually strongly arched; periphery subacute, somewhat lobulate; chambers not inflated, nearly uniform in shape throughout, last few chambers sometimes broader than those in earlier portion of final whorl; chambers increasing slowly in size as added, averaging 14 to 16 in last coil of mature forms; walls coarsely perforate; sutures on dorsal face, gently curved, broad, limbate, flush with surface; sutures on ventral face nearly radial, strongly depressed; elongate, slightly curved, slit-like apertures present between chambers near periphery on ventral face; central portion of test on ventral side covered by large, coarsely pitted boss formed from fused ends of pillars which fill major portion of interior of test. Vertical sections show pillars extending both dorsally and ventrally from initial chambers, those on ventral side long, thick, separating widely as they approach exterior; those on dorsal side short, thin, compactly grouped, spreading slightly as they near surface of test.

Average diameter 1.4 to 1.5 mm., average thickness 0.76 mm.

This is apparently the form figured by Cushman as *Truncatulina* sp. (see synonomy above); unfortunately the types were not available for study at this time. In dorsal view *L. cushmani* is very similar to *Eponides gunteri* Cole. A study of the types of the latter species, deposited at the Florida Geological Survey, suggests the possibility that one of the forms figured by Cole may be *L. cushmani*. However, the specimens are poorly preserved and it would be necessary to section them before a definite conclusion could be reached.

This species is abundant in the Lake City limestone (early Middle Eocene) of Florida. The same form, or a smaller variety is also frequently common in the lower portion of the Oldsmar limestone (Lower Eocene) of the same area.

Types from 1067 and 1078 feet in the Dundee Petrol. Co., "Bushnell Well," Sumter County, Florida. Fla. G. S. no. W-3.

Holotype, U.S.N.M. no. 559723. Paratype, U.S.N.M. no. 559724.

This species is named in honor of Dr. Joseph A. Cushman, who discovered the form and who figured it for the first time.

Genus EPISTOMARIA Galloway, 1933

EPISTOMARIA SEMIMARGINATA (d'Orbigny)

Plate 19, figures 6a–c

Rotalia (*Turbinulina*) *semi-marginata* D'ORBIGNY, 1825, Ann. Sci. Nat., p. 110 (276).

Rotalia semimarginata D'ORBIGNY. 1850, Prodrome de Paléont., vol. 2, p. 407, No. 1317. Type figure. FORNASINI, 1906, R. Acad. Sci. Ist. Bologna, Mem. ser. 6. tomo 3, pl. 4, fig. 5. —TERQUEM, 1882, Soc. géol. France Mém., ser. 3, vol. 2, p. 56, pl. 3, (11) figs. 12–14.

Discorbina rimosa PARKER and JONES, 1865, Philos. Trans., pp. 385, 421, pl. 19, figs. 6a–c.

Epistomella rimosa (Parker and Jones) CUSHMAN, 1928, Cushman Lab. Foram. Research Contr., vol. 4, p. 6, pl. 1, fig. 9, a–c. (After Parker and Jones).—GALLOWAY, 1933, A manual of Foraminifera, p. 282, pl. 25, figs. 10a–c. (After Parker and Jones).—CUSHMAN, 1933, Cushman Lab. Foram. Research Spec. Pub. 5, pl. 30, figs. 17a–c.—Foraminifera, 3rd Ed., 1940, Key pl. 30, figs. 17a–c. (After Parker and Jones).—APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 3, figs. 8a, b, c.

Test moderately large, somewhat oval in outline, slightly longer than broad; dorsal side gently convex, ventral side strongly convex; periphery narrowly rounded, slightly lobulate; chambers distinct, increasing rapidly in size as added, 6 to 8 usually present in adult coil; sutures depressed; on dorsal face, gently curved, with narrow, elongate apertures opened at inner edges of chambers; on ventral face supplementary chambers added about umbilicus which extend out for about three-fourths of distance between umbilical area and periphery; narrow, curved apertures present at outer edges of supplementary chambers; an aperture also present at base of septal face of supplementary chambers; walls thick, finely perforate.

Specimens from the Eocene of Florida were compared with topotypes from the Calcaire Grossier of Grignon (Lutetian) of France and were found to be alike in all respects.

Parker and Jones presumably described the same form but included a recent specimen in their discussion of the species. They also did not state clearly whether an Eocene or the Recent specimen was figured. In regard to this Recent reference Cushman[7] states,

> I have a few specimens of a Recent species from off New Zealand and they seem to be definitely different from the Eocene one, and seem to show that Parker and Jones' figure of '*Discorbina rimosa*' was of an Eocene form, unless the Recent species that we have is different from the one they mention as "Recent: India (on a Clam shell)."

Both Galloway and Cushman apparently used French Eocene specimens as a basis for their studies, but referred the forms which they discussed to *Discorbina rimosa* Parker and Jones. On this subject Dr. Cushman[7] writes,

> I think there is no question but that *semi-marginata* of d'Orbigny, 1826 (1825?) is the same as the *rimosa* of Parker and Jones 1865, although they mention recent material also

Several authors have reported *D. rimosa* from the Recent, but have used the Parker and Jones illustration. As noted above, Dr. Cushman and the writers are doubtful of the identity of the Eocene and Recent species.

Eocene of France; common in the Lake City limestone (early Middle Eocene), rare in the Avon Park limestone (late Middle Eocene) of Florida; Recent?

Plesiotypes from 1040–55 feet in the Suwannee Petrol. Corp. Sholtz No. 1, Levy County, Florida, and 1700 feet in the Pioneer Oil Co., Hecksher-Yarnell No. 1, "Kissengen Springs Well," Polk County, Florida.

Plesiotypes, U.S.N.M. nos. 559725, 559726.

Family AMPHISTEGINIDAE

Genus ASTERIGERINA d'Orbigny, 1839

ASTERIGERINA SUBACUTA FLORIDENSIS Applin and Jordan, n. var.

Asterigerina subacuta floridensis APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 1, figs. 3a, b. (Nomen nudum.)

A varietal form of this common Oligocene species is often abundant in the Suwannee limestone (Oligocene) of Florida and southern Georgia. In the variety the chambers on

[7] Cushman, Joseph A., Private communication.

the dorsal face are narrower, and the inner margins of the chambers in the final coil are abruptly terminated at the point of contact with the spiral suture; this margin is not lobulate and the chambers are not somewhat embracing as in the typical form; on the ventral face, the suture lines between the supplementary chambers and the periphery are much less strongly curved in the variety; the periphery bears a broad, fimbriate keel.

Average diameter 1.20 to 1.40 mm., height 0.40 mm.

Suwannee limestone (Oligocene) of Florida and Georgia.

Holotype from 210–20 feet, in International Mineral and Chemical Corp. Well, Polk County, Florida. Fla. G. S. no. W-639. (Figures in reference given in the synonymy.)

Holotype, U.S.N.M. no. 559727.

Genus AMPHISTEGINA d'Orbigny, 1826

AMPHISTEGINA ALABAMENSIS Applin and Jordan, n. sp.

Plate 21, figures 3a, b

Test small, equally biconvex, umbonate; periphery acute, blunt keel present on some specimens; sutures on dorsal face limbate, ornamented by raised ribs which generally break up into beads near inner margin; umbonal area surrounded by ring of closely spaced beads which often coalesce to form umbonal ring; sutures on dorsal face radiate for about two thirds of their length, strongly recurved near periphery; secondary chambers on ventral face extending about two thirds of distance between umbo and periphery; chambers 15 to 18 in adult specimens; aperture a small opening on periphery at base of septal face of final chamber, sometimes extended ventrally; characteristic granules present.

Average diameter 0.90 to 1.00 mm., thickness 0.27 mm.

This species is frequently abundant in the Ocala limestone (Upper Eocene) of western Florida, southern Georgia and southeastern Alabama. As a rule the specimens are chalky and poorly preserved. They show some variation in ornamentation, as indicated in the description.

Holotype from 550 feet in Escambia Oil and Gas, State Line Land and Lumber Co. No. 1, Escambia County, Alabama.

Holotype, U.S.N.M. no. 559728.

AMPHISTEGINA PINARENSIS COSDENI Applin and Jordan, n. var.

Plate 18, figure 8

Amphistegina pinarensis cosdeni APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 2, figs. 2a, b, 3. (Nomen nudum.)

This species, which was described from the Eocene of Cuba, reappears in a varietal form in the lower member of the Ocala, Upper Eocene, of Florida. The Florida form is apparently closely related to the Cuban species, since typical specimens appeared in two well sections in Florida and will possibly be found at other localities in the state. As a rule, however, the Florida form exhibits certain constant differences which seem to warrant its description as a variety. The chambers of the Florida specimens are less numerous, averaging 15 to 18 in the final coil; the ventral face is broadly convex, usually flaring or widening abruptly near the periphery; and the sutures on the dorsal face are sharply recurved at a point about two thirds of the distance from the umbonal area.

Average diameter 1.50 to 1.70 mm., height 0.73 mm.

This is an important index fossil for the lower member of the Ocala limestone (Upper Eocene) in peninsular Florida.

Holotype from 195–200 feet, Orlando Army Air Base Well, Orange County, Florida. Fla. G. S. no. W-601.

Paratype from 120 feet, Auxiliary Training Field Well, at Montbrook, Levy County, Florida, Fla. G. S. no. W-652. (Figured in reference given in the synonymy.)

Holotype, U.S.N.M. no. 559729. Paratype, U.S.N.M. no. 559730.

APHISTEGINA NASSAUENSIS Applin and Jordan, n. sp.

Plate 21, figures 2a, b

Test unequally biconvex, dorsal face gently convex, ventral face strongly arched, suture lines faint, ornamented by rows of very small, closely spaced beads which diminish rapidly in size and strength as they near periphery; umbonal areas emphasized by group of low nodes; chambers 15 to 17 in the final coil of adult specimens; walls very finely beaded, beading somewhat stronger and coarser on ventral face; sutures on dorsal face gently recurved near periphery; secondary chambers on ventral face extending

about three fourths of distance between umbonal area and outer margin of test; aperture a low-arched opening at base of final chamber on periphery.

Average diameter 1.45 mm., thickness 0.60 mm.

This rather delicately ornamented species is never abundant, but seems to hold a geographically widespread, and narrowly defined stratigraphic position within the Lake City limestone, early Middle Eocene, of Florida. It is usually accompanied by many specimens of the much longer ranging species, *Amphistegina lopeztrigoi* D. K. Palmer.

Holotype from 765–75 feet in City of Lake City Well at Alligator Lake, Columbia County, Florida.

Holotype, U.S.N.M. no. 559731.

Family GLOBIGERINIDAE

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA VELASCOENSIS Cushman

Plate 19, figure 7

Globigerina velascoensis CUSHMAN, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 1, p. 19, pl. 3, fig. 6.—CUSHMAN, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, no. 6, p. 605, pl. 20, fig. 21.—WHITE, 1928, Jour. Paleontology, vol. 2, no. 3, p. 196, pl. 28, fig. 2.—APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pt. 5, fig. 3a, b, c.

This characteristic Velasco species is abundant in the beds of Tamesí (Velasco) age (Paleocene) of northwestern Florida. Cole[8] and Plummer have noted the similarity of this species to the typical Midway species, *Globigerina triloculinoides* Plummer. The writers grant this similarity but are inclined to agree with Plummer in believing that the two species can be separated, since the typical Midway species is much less compressed than the Mexican form with which it is compared. Both species are present in about equal abundance in the Florida materials studied, and both have also been found by E. R. Applin in samples collected by Muir from the type locality of the Velasco shale, in Mexico. Cushman[9] records *G. triloculinoides* from Porters Creek (Midway) horizons in Alabama, which is possibly an updip equivalent of the beds of Tamesí (Velasco) age of Florida.

Plesiotype from core 4055–61 feet in Oil City Corp. Walton Land and Timber Co. Well No. 1, Walton County, Florida.

Plesiotype, U.S.N.M. no. 559732.

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

GLOBOROTALIA cf. G. MEMBRANACEA (Ehrenberg)

Pulvinulina membranacea, CUSHMAN, 1926, Amer. Assoc. Petroleum Geologists Bull., vol. 10, no. 6, p. 608, pl. 21, fig. 10.

Globorotalia membranacea, WHITE, 1928, Jour. Paleontology, vol. 2, p. 280, pl. 38, fig. 1a–c.—Cole, 1938, Florida Geol. Survey Bull. 16, p. 24, pl. 1, figs. 4, 5.—TOULMIN, 1941, Jour. Paleontology, vol. 15, no. 6, p. 608, pl. 82, figs. 4, 5.—CUSHMAN, 1942, Cushman Lab. Foram. Research Contr., vol. 18, pt. 2, p. 45, pl. 8, fig. 10.—APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 5 figs. 3a–c.

Specimens from a number of Tertiary formations have been referred to this species, but the form found in the Paleocene of Florida seems to be closely related, only to those listed in the above synynomy. It is a characteristic fossil of the Tamesí (Velasco) of Mexico and is also common in the Paleocene of northwestern Florida.

Specimen from core 2620–26 feet in the Oil City Corp., Walton Land and Timber Co. Well, Walton County, Florida.

Plesiotype, U.S.N.M. no. 559733.

GLOBOROTALIA VELASCOENSIS (Cushman)

Plate 19, figures 8a, b

Pulvinulina velascoensis CUSHMAN, 1925, Cushman Lab. Foram. Research Contr., vol. 1, Pt. 1, p. 19, pl. 3, fig. 5a–c.—CUSHMAN, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, no. 6, p. 608, pl. 21, fig. 9.

Globorotalia velascoensis, CUSHMAN, 1927, Jour. Paleontology, vol. 1, No. 2, pl. 27, figs. 7–9.—WHITE, 1928, Jour. Paleontology, vol. 2, pt. 4, p. 281, p. 38, fig. 2a–c.—CUSHMAN, 1932, U. S. Nat. Mus. Proc., vol. 80, Art. 14, p. 51, pl. 15, fig. 8a–c.—APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull. vol. 28, no. 12, pt. 5, figs. 4a–c.

This species, which is an abundant and highly characteristic fossil of the Velasco shales of Mexico, is also abundant in the clastic facies of the Paleocene of northwestern Florida. The beading on the sutures of the Florida specimens is not so well devel-

[8] Cole, W. Storrs, Florida Geol. Survey Bull. 16, pp. 24–25, 1938.

[9] Cushman, Joseph A., 1940, Cushman Lab. Foram. Research Contr., vol. 16, pt. 3, pp. 72–73, pl. 12, fig. 15.

oped nor so clearly shown as on some specimens from outcrop localities in Mexico; however, the same feature is equally obscure on many Mexican specimens obtained from buried sections of the Velasco.

Plesiotype from core, 3055–61 feet in Oil City Corp. Walton Land and Timber Co. Well, Walton County, Florida.

Plesiotypes, U.S.N.M. no. 559734.

Family ANOMALINIDAE

Genus ANOMALINA d'Orbigny, 1826

ANOMALINA COSDENI Applin and Jordan, n. sp.

Plate 19, figure 10a–c

Anomalina rubiginosa cosdeni APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pl. 5, fig. 7a, b. (Nomen nudum.)

Test subcircular, close coiled, slightly compressed dorsally, ventrically gently convex; periphery rounded, entire; chambers not inflated, increasing very gradually in size, usually ten in final whorl; sutures moderately curved; on dorsal face, usually low, indistinct, but terminating in row of prominent beads along line of spiral suture, cluster of other beads generally covering earlier whorls over central portion of test; sutures on ventral face raised, broadening and thickening rapidly toward inner ends where they form ring of elongated nodes about umbilicus, which is partially filled with high boss; walls on dorsal face very finely punctuate, on ventral side coarsely punctate; aperture a curved opening at base of septal face on periphery.

Average diameter 0.70 mm., height 0.40 mm.

Beds of Taylor age (Upper Cretaceous) of peninsular Florida.

Types from 4380–4440 feet in the Oil Dev. Co. of Florida, "South Lake Well," J. Ray Arnold farm, Lake County, Florida.

Holotype, U.S N.M. no. 103746. Paratype, U.S.N.M. no. 103747.

ANOMALINA RUBIGINOSA Cushman

Plate 20, figure 4

Anomalina rubiginosa CUSHMAN, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, p. 607, pl. 21, fig. 6a–c.—CUSHMAN AND JARVIS, 1932, U. S. Nat. Mus. Proc., vol. 80, art. 14, p. 52, pl. 16, figs. 3–5.—CUSHMAN, 1940, Cushman Lab. Foram. Research Contr., vol. 16, pt. 2, pp. 31, 32, pl. 6, figs. 1–3.—APPLIN and APPLIN, 1944, Am. Assoc. Petroleum Geologists Bull., vol. 28, no. 12, pt. 5, figs. 1a–c.

This species is a common form in the Velasco shale of Mexico and was reported also from beds of presumably the same age in Trinidad.[10] It is well represented by typical specimens in the beds of Tamesí (Velasco) age (Paleocene) of northern Florida.

Plesiotypes from core 2620–26 feet in the Oil City Corp. Walton Land and Timber Co. Well No. 1, Walton County, Florida.

Plesiotype, U.S.N.M. no. 559735.

Genus PLANULINA d'Orbigny, 1826

PLANULINA WALTONENSIS Applin and Jordan, n. sp.

Plate 20, figures 5a–c

Test much compressed, evolutely coiled, early whorls clearly shown on dorsal side, about two and one half coils visible; ventral side umbilicate; periphery acute, but not keeled; chambers distinct, numerous, about 14 present in adult coil, of uniform shape, not inflated, increasing very gradually in size as added; sutures moderately curved, limbate, raised slightly above surface of test; sutures on ventral side often terminating in small bead at umbilicus, which is partially filled with clear shell material; walls finely perforate; aperture a small opening with slight lip, at base of final chamber on median line.

Average diameter 0.55 to 0.60 mm., height 0.08 mm.

Common in the clastic facies of the Paleocene in northwestern Florida.

Holotype from 2675 feet in Brown-Ravlin, Phillips Well No. 1, sec. 14, T. 3 S., R. 1 E, Wakulla County, Florida.

Holotype, U.S.N.M. no. 559736.

Genus CIBICIDES Montfort, 1808

CIBICIDES HARPERI (Sandidge)

Plate 19, figures 9a, b

Anomalina harperi SANDIDGE, 1932, Am. Mid. Naturalist, vol. 13, p. 316, pl. 29, figs. 1, 2.

Cibicides ripleyensis SANDIDGE(?) 1932 (not *Truncatulina ripleyensis* (W. BERRY), Am. Mid. Naturalist, vol. 13, p. 199, pl. 19, figs. 17–19.

Cibicides harperi (Sandidge) CUSHMAN, 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 3, p. 72, pl. 12, fig. 16.

This species, which was originally de-

[10] Cushman and Jarvis, 1932, U. S. Nat. Mus. Proc., vol. 80, art. 14, p. 52, pl. 16, figs. 3–5.

scribed from the Ripley formation (Upper Cretaceous) of Alabama, is a common and characteristic fossil in the lower division of the Lawson limestone of peninsular Florida, and occurs, also, in beds of Navarro age in northern Florida. Specimens figured in the literature would seem to indicate that this is a variable species, but the Florida forms are reasonably uniform in their appearance. They were compared with topotypes of the Alabama form described by Sandidge and found to agree in all respects. Cushman[11] says of this species, "it seems to be limited to upper beds of Navarro age."

Plesiotype from 2560–70 feet in the J. S. Cosden, W. L. Lawson No. 1, Marion County, Florida.

Plesiotype, U.S.N.M. no. 103748.

[11] Cushman, Joseph A., 1943, Cushman Lab. Foram. Research Contr., vol. 19, pt. 3, p. 72.

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CIBICIDES MISSISSIPPIENSIS OCALANUS Cushman

Cibicides mississippiensis ocalanus CUSHMAN, 1935, U. S. Geol. Survey Prof. Paper 181, p. 54.

This variety is a common and diagnostic fossil in the upper member of the Ocala limestone of Jackson age (Upper Eocene) of Florida.

Plesiotype from 400–40 feet in Federal Ice Co. Well No. 1, at Lakeland, Polk County, Florida.

Plesiotype, U.S.N.M. no. 559737.

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STIGMATELLA IN THE ORDOVICIAN OF THE CENTRAL ONTARIO BASIN

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ABSTRACT.—The trepostomatous bryozoan genus *Stigmatella* is represented in the Central Ontario Basin by 13 species and 9 varieties. Two of these forms are recognized in this area for the first time. Five of the remaining 20 forms have undergone revision as a result of the restudy of the collections of the Royal Ontario Museum of Palaeontology. The species *S. vulgaris* and the variety *S. vulgaris monticulata* are the most abundant representatives of the genus in the Toronto region.

INTRODUCTION

STIGMATELLA is one of the most prolific trepostomatous bryozoan genera in the central Ontario Basin. Coincident with stratigraphic investigations it has been studied within the past 25 years by several paleontologists among whom are W. A. Parks, W. S. Dyer, M. A. Fritz, and J. F. Caley. The perplexing problems of development and interrelationships of the component species and varieties which have been met by these workers have prompted the revision of the genus as it appears in this basin.

With a view, therefore, to obtaining a better understanding of these stratigraphically important fossils, Dr. M. A. Fritz of the Department of Geology, University of Toronto suggested this investigation, and I wish to express my sincere appreciation for her constant advice and encouragement. The manuscript has been revised at Walker Museum, University of Chicago and read by Dr. Carey Croneis to whom thanks are due.

All material available in the collections of the Royal Ontario Museum of Palaeontology has been restudied. Some reclassification has been found necessary. One new species and three new varieties are described. One previously described species has been identified in this basin for the first time, and the genetic and stratigraphical relationships of members of the genus have been established.

HISTORY OF THE STUDY OF THE GENUS

The genus *Stigmatella* was erected by E. O. Ulrich and R. S. Bassler in 1904; the original description is herewith quoted:

> Zoarium encrusting, massive, or sub-ramose; mesopores present, often restricted to small spots; acanthopores small, more or less abundantly developed at intervals between which they are wanting; in the ramose forms they are developed in the extreme outer region.

The above description was extended in the same paper as follows:

> Zoarium variable, ranging from encrusting to irregularly massive and ramose. Zooecia angular, rounded, or irregularly petaloid, the shape depending upon the presence (or absence) of mesopores and the number of acanthopores. Typically the zoarial surface exhibits at regular intervals maculae or spots composed of mesopores, although in some species the usual monticules or clusters of large cells occur. Acanthopores always present but variable in number, intermittent, developed chiefly in narrow zones, sometimes inconspicuous but more often so numerous as to give the surface a decidedly hirsute appearance. Mesopores, when present, developed in the mature region only, their number being variable even for the same species.
>
> The zooecial tubes have thin walls in the axial region and these become but slightly thickened in the peripheral region where a few unusually delicate diaphragms are inserted. In vertical sections the walls exhibit at rather regular intervals in the peripheral region thickenings somewhat similar to those occurring in *Stenopora*. These thickenings occur approximately at the same height in the walls, and tangential sections through these zones give the full development of the acanthopores. Minute structure of walls as shown in tangential sections, of the type that characterizes the *Heterotrypidae*.

Since the publication of Ulrich and Bassler's original paper contributions of several other investigators have added to knowledge of this genus in North America. Ulrich and Bassler originally described six species: *S. crenulata* (the genotype), *S. interporosa*, *S. nana*, *S. nicklesi*, *S. personata*, and *S. spinosa*. They included in addition three other species of bryozoa: *Leptotrypa clavis* Ulrich,

Monticulipora (*Monotrypa*) *dychei* James, and *Leptotrypa irregularis* Ulrich.

R. S. Bassler (1906), in his report on the bryozoan fauna of the Rochester shale, described a new species *S. globata* which he found to be not uncommon at that horizon.

E. R. Cumings (1908) noted the occurrence in the Cincinnatian of Indiana of *S. clavis* (Ulrich), *S. crenulata* Ulrich and Bassler, *S. irregularis* (Ulrich), *S. personata* Ulrich and Bassler, and *S. spinosa* Ulrich and Bassler.

R. S. Bassler (1911) reported from the Middle Ordovician of the Baltic region *Callopora foordii* Nicholson and *Leptotrypa claviformis* Ulrich, both of which he assigned to the genus *Stigmatella*. In addition he described two new species *S. massalis* and *S. inflecta*. *S. claviformis* (Ulrich) is known to occur also in the Decorah shale of Iowa and Minnesota.

E. R. Cumings and J. J. Galloway (1913) recorded from the Cincinnatian of Indiana all of Ulrich and Bassler's species with the exception of *S. interporosa* and *S. nana*. They described the new species: *S. alcicornis* *S. catenulata*, *S. incrustans*, and *S. sessilis*.

A. F. Foerste (1916) listed several species of *Stigmatella* from the Workman's Creek section of Ontario, including *S.* cf. *S. nicklesi* Ulrich and Bassler and two *Stigmatella sp.* from beds he regarded as Eden and Maysville correlatives. From the "Eden" of Manitoulin Island he recorded *S. clavis* (Ulrich) and *S. nana* Ulrich and Bassler; and from an undefined "Lorraine" horizon at Toronto he listed an undetermined species of *Stigmatella*.

W. A. Parks and W. S. Dyer (1922) recognized in the rocks at Toronto the presence of *S. crenulata* Ulrich and Bassler, *Stigmatella* cf *S. personata* Ulrich and Bassler, and *Stigmatella* cf. *clavis* (Ulrich). In addition they described the following new forms: *S. catenulata* var. (*a*), *S. catenulata* var. (*b*), *S. catenulata diversa*, *S. lambtonensis*, and *S. vulgaris*.

W. S. Dyer (1925) noted in the Credit River section near Toronto the occurrence of *S. crenulata* Ulrich and Bassler, *S. incrustans* Cumings and Galloway, *S. interporosa* Ulrich and Bassler, *Stigmatella* cf. *S. lambtonensis* Parks and Dyer, and *S. catenulata* var. (*b*) Parks and Dyer. He supplemented this list with descriptions of one new species, *S. hybrida*, and two new varieties: *S. sessilis crassa* and *S. personata lobata*.

M. A. Fritz (1926) described from the Workman's Creek section two new species, *S. intermedia* and *S. peculiaris*, and also three new varieties: *S. crenulata meafordensis*, *S. sessilis delicatula*, and *S. vulgaris ramosa*.

J. F. Caley (1936) listed from the Wekwemikongsing formation of Manitoulin Island *S. nana* Ulrich and Bassler. He also recorded from the Meaford formation *S. personata lobata* Dyer, and described a new variety *S. peculiaris similas* from the Wekwemikongsing.

Lastly, Helen Duncan (1939) greatly extended the range of the genus by describing two new species from the Traverse group of Michigan, *S. alpenensis* and *S. hybrida*. The latter name was previously used by Dyer (1925) for a species of *Stigmatella*, but as yet no new name for the Traverse species has been proposed.

NOTES ON PREVIOUSLY ESTABLISHED SPECIES AND VARIETIES

STIGMATELLA ALCICORNIS Cumings and Galloway

Text figures 3, 4, 10

Stigmatella alcicornis CUMINGS AND GALLOWAY, 1913, Indiana, Dept. Geol. and Nat. Res. 37th Ann. Rept., p. 436, pl. 18, figs. 1–1e.

This species is represented in the Toronto collections by a single specimen. The zoarium is slightly thicker than in the type, being 4 to 5 mm. in thickness. In tangential section also this specimen is slightly atypical in that there are 8 or 9 zooecia in 2 mm., rather than 7 or 8. Mesopores are approximately the same as in the type. Acanthopores are somewhat fewer in number. The vertical section is typical except that it shows a few chain-like mesopores in the peripheral region.

Occurrence.—Humber member, Dundas formation at Humbervale quarry, near Toronto, Ontario.

Plesiotype.—Royal Ontario Museum of Palaeontology, no. 1180 H.R.

STIGMATELLA CATENULATA Cumings and Galloway

Stigmatella catenulata CUMINGS AND GALLOWAY, 1913, Indiana, Dept. Geol. and Nat. Res.

37th Ann. Rept., p. 437, pl. 19, figs. 1–1c.
Stigmatella catenulata PARKS AND DYER, 1922, Ontario Dept. Mines, 30th Ann. Rept., pt.7, p. 12, pl. 3, figs. 1, 1a, 2, 3; pl. 4, figs. 1, 2, 3.

This species is represented by the form referred by Parks and Dyer to *S. catenulata* var. (*a*). Their plesiotype is the only specimen in the collections and does not show sufficient individual characteristics to warrant the erection of a separate variety. The Toronto specimen was found at a horizon considerably lower than the correlative of the Arnheim of Indiana from which the species was recorded by Cumings and Galloway. The range of the species is, therefore, somewhat extended.

The plesiotype of *S. catenulata* var. (*a*) becomes now *S. catenulata*.

Occurrence.—Humber member, Dundas formation at five-foot level, Lambton shale pits, Toronto, Ontario.

Plesiotype.—Royal Ontario Museum of Palaeontology, no. 1087 H.R.

STIGMATELLA CLAVIS (Ulrich)

Leptotrypa clavis ULRICH, 1883, Cincinnati Soc. Nat. History Jour., vol. 6, p. 161, pl. 6, figs. 3, 3a.
Stigmatella clavis ULRICH AND BASSLER, 1904, Smithsonian Misc. Coll. Quart., vol. 47, p. 34, pl. 10, fig. 4.
Stigmatella clavis CUMINGS, 1908, Indiana Dept. Geol. and Nat. Res. 32nd Ann. Rept., p. 881, pl. 24, figs. 2, 2a; pl. 25, fig. 3.
Stigmatella cf. *S. clavis* PARKS AND DYER, 1922, Ontario Dept. Mines, 30th Ann. Rept., pt. 7, p. 16.

Three specimens referred to *Stigmatella* cf. *S. clavis* by Parks and Dyer have been referred to *S. halysa* by the present writer. The original identification of these specimens was evidently based mostly upon external form. Internal structure, as indicated by thin sections, suggests relationship with *S. halysa* rather than with *S. clavis*.

This species has not been found in the Toronto region, but Foerste has recorded it definitely from the "Eden" of Manitoulin Island. The type was collected by Ulrich from the Utica formation.

STIGMATELLA CRENULATA Ulrich and Bassler

Text figures 1, 2

Stigmatella crenulata ULRICH AND BASSLER, 1904, Smithsonian Misc. Coll. Quart., vol. 47, p. 34, pl. 9, figs. 1–4; pl. 14, figs. 1, 2.
Stigmatella crenulata CUMINGS, 1908, Indiana Dept. Geol. and Nat. Res. 32nd Ann. Rept., p. 882, pl. 24, figs. 4–4d.
Stigmatella crenulata PARKS AND DYER, 1922, Ontario Dept. Mines, 30th Ann. Rept., pt. 7, p. 12, pl. 3, figs. 4, 5, 7; pl. 4, figs. 4, 5.
Stigmatella crenulata DYER, 1925, Ontario Dept. Mines, 32nd Ann. Rept., pt. 7, p. 54, pl. 4, fig. 6; pl. 7, fig. 6.

This species, the genotype, was originally described from the lower Richmond of Ohio. The strata forming the banks of the Humber river at Toronto have yielded many specimens referred by Parks and Dyer to it. Lack of inflection of the zooecial walls by acanthopores in the peripheral region seems to justify referring them to *S. vulgaris*. Consequently their plesiotype, No. 1086 H.R. becomes a topotype of *S. vulgaris*.

S. crenulata does occur, however, in the Meaford formation as exposed in the Credit river near Streetsville, Ontario. The plesiotype of Dyer, no. 12220, does not show all the features characteristic of *S. crenulata* but another, no. 12297, does and is herein figured.

Occurrence.—Erindale member, Meaford formation in Credit River at Streetsville, Ontario.

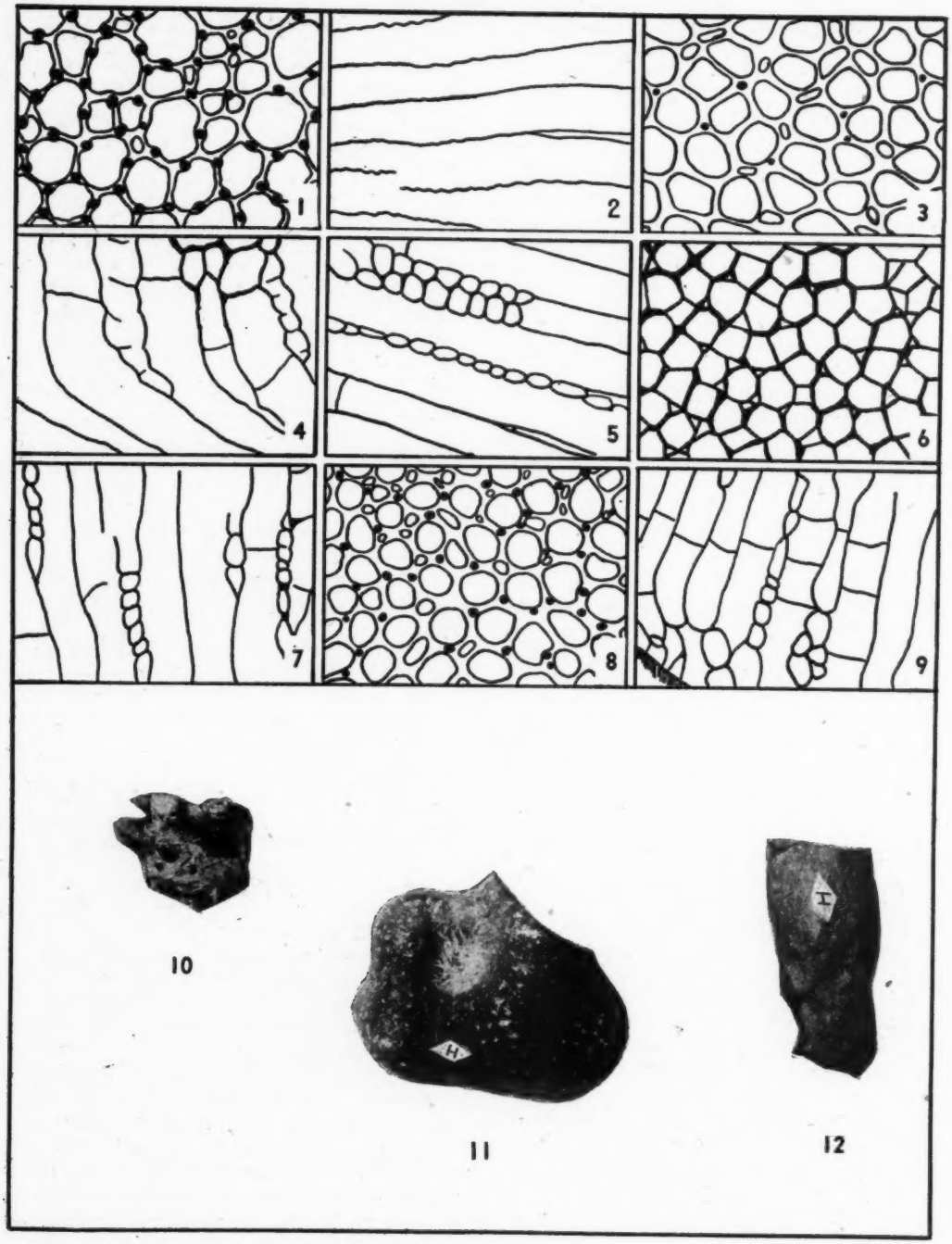
Plesiotype.—Royal Ontario Museum of Palaeontology, no. 12297.

STIGMATELLA PERSONATA Ulrich and Bassler

Stigmatella personata ULRICH AND BASSLER, 1904, Smithsonian Misc. Coll. Quart., vol. 47, p.36, pl. 12, figs. 1–3.
Stigmatella personata CUMINGS, 1908, Indiana Dept. Geol. and Nat. Res. 32nd Ann. Rept. p. 884, pl. 24, figs. 3, 3d.
Stigmatella cf. *S. personata* PARKS AND DYER, 1922, Ontario Dept. Mines, 30th Ann. Rept., pt. 7, p. 16, pl. 3, fig. 6; pl. 4, figs. 6, 7.

This species was originally recorded from the Richmond formation of Hanover, Ohio. Cumings recorded it from the Elkhorn, uppermost Richmond of Indiana.

Parks and Dyer have referred to this species several specimens, including the two plesiotypes, nos. 1092 H.R. and 1093 H.R. from the Humber member of the Dundas formation at Toronto. The former is now recognized as an example of a new variety, *S. vulgaris monticulata*, for which it becomes a topotype. The other plesiotype is represented only by two thin sections which are too poor for positive identification and they are now referred to *Stigmatella* sp. indet.



FIGURES 1–12

None of the other specimens shows the characters of *S. personata;* they are all identified as different species of *Stigmatella.*

The occurrence of *S. personata* at a horizon in the Dundas formation, although not impossible, is not to be expected.

STIGMATELLA VULGARIS Parks and Dyer

Stigmatella vulgaris PARKS AND DYER, 1922, Ontario Dept. Mines, 30th Ann. Rept., pt. 7, p. 15, pl. 1, figs. 13, 14; pl. 6, fig. 12.

S. vulgaris is undoubtedly the most common species of *Stigmatella* in the central Ontario Basin. Although specimens encrusting crinoid columns are not uncommon, this species is represented mostly by large irregular masses resembling puffballs.

S. vulgaris was originally described by Parks and Dyer from the Danforth member of the Dundas formation as exposed in the Don Valley Brickyard. Recent collecting along the banks of the Humber river, however, has revealed its great abundance also in the Humber member.

In their original description Parks and Dyer mention a single specimen which shows monticulations. The collection of additional material has yielded a considerable number of monticulate specimens. Because of its constancy this form is described on a later page as a new variety, *S. vulgaris monticulata.*

Parks and Dyer's plesiotype of *S. crenulata,* no. 1086 H.R. from the Dundas formation, is a topotype of *S. vulgaris.*

Occurrence.—Danforth member, Dundas formation in Don Valley Brickyard at Toronto, Ontario.

Plesiotype.—Royal Ontario Museum of Palaeontology, no. 1091 H.R.

NOTES ON SPECIES PREVIOUSLY IDENTIFIED AS STIGMATELLA

DEKAYIA LAMBTONENSIS (Parks and Dyer)

Stigmatella lambtonensis PARKS AND DYER, 1922, Ontario Dept. Mines, 30th Ann. Rept., pt. 7 p. 14, pl. 2, fig. 13.

Stigmatella lambtonensis DYER, 1925, Ontario Dept. Mines, 32nd Ann. Rept., pt. 7, p. 55, pl. 5, fig. 8.

The present investigation has shown that Parks and Dyer's holotype no. 1090 H.R., from the Humber member of the Dundas formation, shows features which definitely exclude it from the genus *Stigmatella.* It is now considered to be a specimen of *Dekayia.* The plesiotype, no. 12244, described by Dyer from the Erindale member of the Meaford formation is selected as the type of the new variety *S. halysa erindalensis.*

There seems to be no adequate basis for the recognition of a species *S. lambtonensis.*

DESCRIPTIONS OF NEW SPECIES AND VARIETIES

STIGMATELLA HALYSA Armstrong, n. sp.

Text figures 5, 12

Stigmatella catenulata var. (*b*) PARKS AND DYER,

EXPLANATION OF FIGURES 1–12

FIGS. *1, 2—Stigmatella crenulata* Ulrich and Bassler. Erindale member, Meaford formation, Credit River, Streetsville, Ontario; Roy. Ontario Mus. Palaeontology no. 12297. *1,* Tangential section, ×30; *2,* Vertical section, ×30. (p. 151)

3, 4, 10—Stigmatella alcicornis Cumings and Galloway. Humber member, Dundas formation, Humbervale quarry, near Toronto, Ontario; Roy. Ontario Mus. Palaeontology no. 1180 H. R. *3,* Tangential section, ×30; *4,* Vertical section, ×30; *10,* External view, ×7/9. (p. 150)

5, 12—Stigmatella halysa Armstrong, n. sp. Holotype, Humber member, Dundas formation, Lambton shale pits, Ontario; Roy. Ontario Mus. Palaeontology no. 1088 H.R. *5,* Vertical section, ×30; *12,* External view, ×5/7. (p. 154)

6, 7—Stigmatella halysa crassa Armstrong, n. var. Holotype, Credit member, Dundas formation, Credit River, Erindale, Ontario; Roy. Ontario Mus. Palaeontology no. 1129 H.R. *6,* Tangential section, ×30; *7,* Vertical section, ×30. (p. 154)

8, 9—Stigmatella halysa erindalensis Armstrong, n. var. Holotype, Erindale member, Meaford formation, Credit River, Streetsville, Ontario; Roy. Ontario Mus. Palaeontology no. 12244. *8,* Tangential section, ×30; *9,* Vertical section, ×30. (p. 154)

11—Stigmatella vulgaris monticulata Armstrong, n. var. Holotype, Humber member, Dundas formation, Humber River, Toronto, Ontario; Roy. Ontario Mus. Palaeontology no. 1516 H.R. External view, ×½. (p. 155)

1922, Ontario Dept. Mines, 30th Ann. Rept., pt. 7, p. 12, pl. 3, fig. 3; pl. 4, fig. 3.

Zoarium encrusting; type specimen encircles crinoid column for at least 90 mm.; maximum thickness 22 mm.; resultant form somewhat cylindrical, tapering slightly to each end; surface nearly smooth, but showing some inconspicuous, low rounded elevations spaced irregularly; zooecial openings in elevations slightly larger than elsewhere.

Two sizes of zooecia in tangential section; larger, 8 in 2 mm., smaller, 10 or 11 in 2 mm.; openings circular to subcircular; walls moderately thick. Acanthopores numerous, about 10 in 10 zooecia; mostly in angles of junction, but also found slightly inflecting walls of zooecia; size no. 1 in Cumings and Galloway's scale, that is, about 1/20 mm. in diameter; central lumen clear, about 1/75 mm. in diameter. Mesopores rather common, suggestion of aggregation in one spot in type.

Vertical sections indicate zooecia have thin, straight walls with characteristic periodic thickening; featured by chain-like mesopores beginning at midradius, continuing to periphery of zoarium; number of "links" 4 to 15. Acanthopores numerous, traceable almost into axial region; diaphragms sparsely developed, tending to appear simultaneously in all zooecia; no noteworthy peripheral thickening of walls.

Remarks.—This fossil was identified by Parks and Dyer as *S. catenulata* var. (*b*). The specific name *halysa* has been given in recognition of the characteristic chain-like mesopores. This species resembles *S. catenulata* from which it may be distinguished chiefly by its habit of growth, and by the size and distribution of the acanthopores which, in *S. catenulata*, are small, inconspicuous, and restricted to the angles of junction of the zooecia. The species has considerable vertical range for, although the type is from the Humber member of the Dundas formation, the Danforth member has yielded additional specimens.

Occurrence.—Humber member, Dundas formation at seven-foot level, Lambton shale pits, Ontario.

Holotype (formerly plesiotype of *S. catenulata* var. (*b*)).—Royal Ontario Museum of Palaeontology, no. 1088 H.R.

STIGMATELLA HALYSA CRASSA
Armstrong, n. var.
Text figures 6, 7

Stigmatella sessilis crassa DYER, 1925, Ontario Dept. Mines, 32nd Ann Rept., pt. 7, p. 72, pl. 6, fig. 10.

Zoarium tightly encrusts fragment of *Isotelus* to thickness of 20 mm. Thin sections show very close affinities with *S. halysa*. In tangenital section zooecia are thin-walled; subpolygonal to subcircular; 10 or 12 in 2 mm.; acanthopores both in angles of junction and inflecting walls of zooecia; mesopores few in number. Vertical sections are identical to *S. halysa* except for less numerous acanthopores.

Remarks.—This variety, from the Credit member of the Dundas formation, for which it is a useful horizon marker, was named by Dyer *S. sessilis crassa*. Thin sections show, however, that one of the diagnostic features of *S. sessilis* is absent, namely, the presence in the axial region of diaphragms spaced apart at approximately the diameter of the zooecial tubes. The peculiar habit of growth and close relationships with *S. halysa* seem to warrant the conclusion that this form is a variety of *S. halysa*.

Occurrence.—Credit member, Dundas formation in Credit River at Erindale, Ontario.

Holotype.—Royal Ontario Museum of Palaeontology, no. 1129 H.R.

STIGMATELLA HALYSA ERINDALENSIS
Armstrong, n. var.
Text figures 8, 9

Zoarium encrusts fragment of pelecypod shell to thickness of 5 mm. and gives off two branches; surface smooth, no evidence of maculae or monticules. In tangential section zooecia moderately thick-walled, rounded to subcircular; somewhat smaller than in *S. halysa*, 11 or 12 in 2 mm.; acanthopores and mesopores few and scattered. In vertical section zooecia show thin straight walls; diaphragms numerous due to close succession of growth stages indicated by slight increase in thickness of walls and presence of acanthopores.

Remarks.—The type specimen of this variety, no. 12244, was formerly a plesiotype of *S. lambtonensis*, which species is now unrecognized, the holotype being referred to the genus *Dekayia*. It closely resembles *S. halysa*

DISTRIBUTION OF SPECIES AND VARIETIES OF STIGMATELLA

Locality	Ohio and Indiana			Manitoulin Island			Toronto Region		Workman's Creek	
Name \ Horizon	Eden	Maysville	Richmond	Sheguiandah	Wekwemikongsing	Meaford	Dundas	Meaford	Dundas	Meaford
S. alcicornis Cumings and Galloway		x					x			
S. alpenensis Duncan[1]										
S. catenulata Cumings and Galloway			x				x			
S. catenulata diversa Parks and Dyer							x			
S. claviformis (Ulrich)[2]										
S. clavis (Ulrich)	x	x		x						
S. crenulata Ulrich and Bassler			x					x		
S. crenulata meafordensis Fritz									x	
S. dychei (James)		x								
S. foordii (Nicholson)[3]										
S. globata Bassler.[4]										
S. halysa Armstrong, *n. sp.*							x			
S. halysa crassa Armstrong, *n. var.*							x			
S. halysa erindalensis Armstrong, *n. var.*								x		
S. hybrida Dyer								x		
S. hybrida Duncan[1]										
S. incrustans Cumings and Galloway			x					x		
S. inflecta Bassler[3]										
S. intermedia Fritz							x		x	
S. interporosa Ulrich and Bassler			x					x		
S. irregularis (Ulrich)		x								
S. massalis Bassler[3]										
S. nana Ulrich and Bassler	x			x	x					
S. nicklesi Ulrich and Bassler	x	x							x	
S. peculiaris Fritz									x	x
S. peculiaris similis Caley					x					
S. personata Ulrich and Bassler			x							
S. personata lobata Dyer						x		x		
S. sessilis Cumings and Galloway		x								
S. sessilis delicatula Fritz									x	
S. spinosa Ulrich and Bassler			x							
S. vulgaris Parks and Dyer							x			
S. vulgaris monticulata Armstrong, *n. var.*							x			
S. vulgaris ramosa Fritz									x	

[1] Reported from Traverse group of Michigan.
[2] Reported from Decorah shale of Minnesota and Iowa, and from Middle Ordovician of Baltic.
[3] Reported from Middle Ordovician of Baltic provinces.
[4] Reported from Rochester shale of New York.

and is considered to be a variety of that species because of its peculiar manner of growth and internal features.

Occurrence.—Upper Erindale member, Meaford formation in Credit River at Streetsville, Ontario.

Holotype.—Royal Ontario Museum of Palaeontology, no. 12244.

STIGMATELLA VULGARIS MONTICULATA
Armstrong, n. var.
Text figure 11

Stigmatella vulgaris PARKS AND DYER, 1922, Ontario Dept. Mines, 30th Ann. Rept., pt. 7, p. 15, pl. 1, figs. 13, 14; pl. 6, fig. 12.

Surface of zoarium covered with slightly raised monticules; in some, monticules 2

mm. in diameter occur at intervals of 3 mm., in others, they are larger, 3 mm. in diameter, but spaced at 2 mm. intervals. Internal structure identical with that of *S. vulgaris;* in tangential section with 6 or 7 larger zooecia in 2 mm., and 10 smaller tubes in 2 mm.

Remarks.—The original description of *S. vulgaris* is as follows:

> This seems to be a variable species of *Stigmatella* of which the zoarium is of considerable size, massive, nodose, sub-hemispherical, or even thick discoidal in shape.
>
> The surface is smooth, and maculae are indidicated only by clusters of larger cells very distinctly developed at intervals. Tangential sections very near the surface show zooecia of very irregular size and shape with thick walls and numerous large acanthopores. We are inclined to regard the smaller cells as young zooecia rather than as mesopores. In places the cells are somewhat larger, but no other difference is observed. Deep tangential sections are strikingly different; the same irregular character of the tubes is seen, but the walls are extremely thin and the acanthopores less numerous and very small.
>
> Vertical sections show very thin-walled zooecia crossed by a few diaphragms chiefly in the peripheral zone. No structures which can be interpreted as distinct mesopores are seen. In places the walls are crenulated and in others quite straight.

Since the publication of this description a monticulate variety has been found in considerable abundance. To this variety the name *S. vulgaris monticulata* has been given in view of the surface features. Specimen no. 1092 H.R., originally figured as a plesiotype of *S. personata*, is a topotype of *S. vulgaris monticulata.*

Occurrence.—Humber member, Dundas formation, in Humber River, Toronto, Ontario.

Holotype.—Royal Ontario Museum of Palaeontology, no. 1516 H.R.

SUMMARY AND CONCLUSIONS

From this study and a survey of the available literature the following table has been drawn up to indicate the distribution of all described species and varieties of *Stigmatella.*

Thirteen well defined species and 9 varieties of *Stigmatella* occur in the Cincinnatian rocks of the Central Ontario Basin. Of these 22 forms, only two are actually recognized in this area for the first time. These are *S. alcicornis* Cumings and Galloway and *S. vulgaris monticulata* Armstrong. Of the remaining 20 forms, 5 have undergone revision, three being given new names. The proposed changes are as follows:

(1) *S. catenulata* Cumings and Galloway, as it stands at the present time, was previously regarded in this area as *S. catenulata* var. (*a*). By abandoning this unnamed variety of Parks and Dyer, and by recognizing the species, the range of *S. catenulata* is lowered to include the Dundas formation.

(2) *S. halysa* Armstrong was previously Parks and Dyer's *S. catenulata* var. (*b*).

(3) *S halysa crassa* Armstrong was originally *S. sessilis crassa* Dyer.

(4) *S. halysa erindalensis* Armstrong was originally *S. lambtonensis* Parks and Dyer. This new variety is described from the plesiotype of *S. lambtonensis* selected by Dyer from the Erindale member of the Meaford formation.

(5) The species *S. lambtonensis* Parks and Dyer, from the Humber member of the Dundas formation, is believed to be invalid, and the holotype, as noted, is referred to the genus *Dekayia.*

Accompanying this revision new illustrations and emended descriptions are presented. The investigation has further shown that the species *S. vulgaris* and the variety *S. vulgaris monticulata* are the most abundant representatives of the genus in the Toronto region.

Finally, as will be shown in a subsequent paper, an attempt has been made to arrange the species and varieties in evolutionary series. In these series will be included, not only the Ontario forms, but also species from the Cincinnati Basin. Two distinct natural subdivisions of the genus have been recognized, differing in internal structure as revealed in vertical sections.

REFERENCES

BASSLER, R. S., 1906, The Bryozoan fauna of the Rochester shale: U. S. Geol. Survey, Bull. 292, p. 28, pl. 14, figs. 6–9.

——, 1911, The early Paleozoic Bryozoa of the Baltic provinces: U. S. Nat. Mus., Bull. 77, pp. 210–217.

CALEY, J. F., 1936, The Ordovician of Manitoulin Island: Canada Geol. Survey, Mem. 202, pp. 21–92.

CUMINGS, E. R., 1908, The stratigraphy and paleontology of the Ordovician rocks of Indiana: Indiana Dept. Geol. and Nat. Res., 32nd Ann. Rept., pp. 605–1190.

—— and GALLOWAY, J. J., 1913, The stratigraphy and paleontology of the Tanner's Creek section of the Cincinnati series of Indiana: Indiana Dept. Geol. and Nat. Res., 37th Ann. Rept., pp. 353–479.

DUNCAN, HELEN, 1939, Trepostomatous Bryozoa from the Traverse group of Michigan: Michigan Univ. Contr. Mus. Paleontology, vol. 5, no. 10, pp. 232–234.

DYER, W. S., 1925, The stratigraphy and palaeontology of Toronto and vicinity, pt. V—The Palaeontology of the Credit River section: Ontario Dept. Mines, 32nd Ann. Rept., pt. 7, 1923, pp. 47–88.

FOERSTE, A. F., 1916, Upper Ordovician formations in Ontario and Quebec: Canada Geol. Survey, Mem. 83, p. 199.

FRITZ, M. A., 1926, The stratigraphy and palaeontology of the Workman's Creek section of the Cincinnatian series of Ontario: Roy. Soc. Canada Trans., 3d ser., vol. 20, sect. 4, pp. 77–108.

PARKS, W. A., and DYER, W. S., 1922, The stratigraphy and palaeontology of Toronto and vicinity, pt. II—The Molluscoidea: Ontario Dept. Mines, 30th Ann. Rept., pt. 7, 1921.

ULRICH, E. O. and BASSLER, R. S., 1904, A revision of the Paleozoic Bryozoa, pt. II—On genera and species of Trepostomata: Smithsonian Misc. Coll., vol. 47, p. 24, pp. 33–37.

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PROBLEMS OF SPECIATION AND CORRELATION AS APPLIED TO MOLLUSKS OF THE MARINE CENOZOIC

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ABSTRACT.—The problems of Cenozoic speciation, migration and correlation are discussed in the light of the modern concept of geographical species as applied to paleontology. Mutations are believed to be genetic and not directly related to environment. Species constantly change and new adaptations are made possible by the appearance of new mutants and the disappearance of old ones.

Accumulating evidence indicates that the rate of specific change, at least in minor details, has been fairly constant irrespective of whether environment changed or not. Other major changes have resulted from adaptation but the production of new species is not entirely attributable to natural selection. Correlation of Cenozoic strata in different major provinces based on the mollusca is difficult because of the restricted habitats of most species. Temperature was most important in the geographical differentiation of faunas into distinct provinces. From the beginning of the Oligocene to the end of the Pleistocene, temperature zones were especially sharply defined and very similar to those that exist today.

A majority of the molluscs live in comparatively shallow water and most species and a large proportion of genera are adapted to definite temperature ranges. Arctic and tropic faunas have little in common but a few species range into neighboring zones. Adaptation to temperature makes extensive north and south migration impossible. Tropical faunas on opposite sides of the Isthmus of Suez or the Isthmus of Panama are very different because they have been isolated by land barriers since the Eocene and late Miocene respectively. Some stenothermal and eurabathal species may have migrated across the Pacific or Atlantic by travelling along the ocean floors. Other molluscs may have been transported across the oceans in their brief free swimming larval stages or by rafting. Such geographically wide ranging species furnish evidence for correlations between major provinces.

Very probably other groups of invertebrates such as the Foraminifera and Radiolaria may furnish a better basis for correlation.

INTRODUCTION AND ACKNOWLEDGMENTS

THIS paper proposes to discuss the problems of speciation and correlation as applied to the marine Cenozoic deposits by means of marine invertebrates, with special emphasis laid upon the Mollusca. Details pertaining to the correlation of these deposits throughout the world, however, are not discussed because at present there are few paleontologists who would agree upon any proposed detailed correlation table. It is generally recognized that the establishment of exact correlations for the Cenozoic system is very difficult, possibly more so than for any post-Proterozoic system. What is most needed is agreement as to the general principles underlying the criteria to be accepted.

The writer has received many suggestions and helpful criticisms from Prof. A. S. Campbell (Zoology Department, St. Mary's College), Prof. E. B. Babcock (Department of Genetics, University of California at Berkeley) and from Dr. R. A. Stirton (Curator of Mammals, Museum of Paleontology, University of California at Berkeley).

BIOLOGICAL PRINCIPLES

Three important fields of modern biology which must be considered in any discussion of criteria for correlation by means of fossil organisms are taxonomy, genetics and geographical distribution. They are so closely tied together that it is very difficult to discuss the application of one without referring to the others.

Taxonomy, the classification of plants and animals, has been revolutionized as a result of comparatively recent studies in genetics and geographical distribution. The modern view as to what constitutes a species is very different from that generally held a few years ago.

The generally accepted basis for establishing paleontological correlations by means of marine invertebrates is what may be termed the identity of species method. This

might better be called the identity of genera and species method for the genus and species concept is more or less subjective, the genera in some groups being equivalent to the species in other groups, depending upon the taxonomist.

General acceptance of the species method is based upon experience and the data collected by paleontologists through more than one hundred years. It has long been recognized that fossil species have definite geologic ranges and that the more generalized or simple types have longer ranges than the more highly specialized or ornamented ones. Another important fact, backed by innumerable observations, is that once a species becomes extinct it never reappears. A species may have a longer time range than is now suspected and future collecting will undoubtedly extend the ranges of many forms. Each species, however, has a definite life period more or less accurately known, and when two identical forms are found in strata of two separate areas these identical forms may be considered to have lived more or less contemporaneously and therefore the deposits in which they are found belong to the same time-period. The accuracy of such a correlation depends upon the kind of species, whether it represents a generalized or specialized type and upon the adequacy with which its time range has been determined. The shorter the life period of the species, the more valuable it is for correlation purposes.

The identity of species method raises several problems that require consideration. (1) What is a species, a subspecies or a variety? (2) How are species formed? (3) How do migrations of marine invertebrate species take place? Very little that is new can be added here to answer these questions but it seems worth while to review some of the ideas that are generally accepted by modern biologists, to point out their applications to the concepts of paleontological correlation, and to indicate the difficulties that arise.

WHAT IS A SPECIES AND HOW IS IT FORMED?

As generally recognized, a species is a group of individuals living together and crossing one with the other, possessing a complex of genes, which may be differently combined in different individuals. As stated by Simpson (1943, pp. 146–147)

> A species in nature is a group of organisms. It is not a process, as some geneticists say; or an infinite mathematical abstraction, as some statisticians maintain; or a collection of individual specimens, as no one is likely to say but as many, perhaps most, working taxonomists seem unconsciously to assume. The group arises by dynamic genetic processes, it can be described and interpreted by statistical methods, and it is composed of individuals, but it is the group itself that is a species.
>
> . . . In modern taxonomy it is a basic concept that the species in nature is a genetic group—a genetic species is a group of organisms so constituted and so situated in nature that a hereditary character of any one of these organisms may be (possibly but not necessarily) transmitted to a descendant of any other.
>
> . . . Again subject to exception and modification for special cases, and again inapplicable to successive stages in vertical sequences, a species may be defined morphologically more or less as follows: a morphological species is a group of individuals that resemble each other in most of their visible characters, sex for sex and variety for variety, and such that adjacent local populations within the group differ only in variable characters that intergrade marginally.

One of the most important concepts now generally held by biologists and borne out by the more recent genetic studies is that the distinctive mutations that make up a species are the result of changes that take place in the germ plasm rather than a direct response to environment, that these changes are inherent in the germ plasm, and that new mutations are constantly making their appearance while old ones disappear.

Modern genetic studies find very little in the changes of the genes that can be attributed to the direct influence of environment upon the body cells of the organism. One of the great biologic questions, even today, is what produces these changes. Biologic experimentation has not yet solved this problem.

> Be that as it may, the fact remains, that among the present generation no informed person entertains a doubt of the validity of the evolutionary theory in the sense that evolution has occurred and yet nobody is audacious enough to believe himself in possession of the knowledge of the actual mechanism of evolution. (Theodosus Dobzhansky, 1941, p. 8.)

Studies of the geographical distribution of living faunas and floras have resulted in the modern concept that a species is dynamic,

constantly changing, and never static. Genetic studies have attempted to interpret some of the underlying fundamental causes. At present the concept of geographical species is so well understood that it is not necessary to review the detailed evidence that has led to its acceptance. It is founded upon an enormous amount of data, mostly collected during the last hundred years.

Although there are many difficulties modern taxonomists agree that the concept of geographical species fits observed facts better than any other. A geographical species may be defined briefly as a group of individuals which are crossing and which can be separated from another group of the same lineage by the fact that there are no intergrades between individuals of the two groups.

Certain biologists maintain that the test of a species should be that of fertility, and that distinct species do not cross. Accumulating evidence shows that many groups of organisms which are generally accepted as distinct species may be crossed. Huxley (1940, p. 11) states

> Failure to interbreed or to produce fertile offspring is the nearest approach to a positive criterion. It is however meaningless in apogamous forms; and as a negative criterion it is not applicable; many obviously distinct species especially of plants, yielding fertile offspring, often free Mendelian recombination on crossing. A combination of criteria is needed with some sort of flair.

Geographical distribution studies have demonstrated repeatedly that two groups of individuals belonging to the same lineage and showing no intergradations, almost invariably are found to be isolated by some kind of barrier. The types of barriers that may exist have been discussed by numerous writers and need not be reviewed here. All evidence points to the conclusion that the degree of difference existing between related species or subspecies depends upon the time factor and that the longer they have been completely isolated, the greater the difference between them.

Subspecies are smaller groups within areas occupied by the larger groups. In the province of a species smaller areas or subprovinces contain individuals which are more or less, but not completely, isolated. There is commonly gradation between the individuals of the smaller groups, especially between those of adjacent groups.

> The subspecies is composed of a group of local populations and can be distinguished from other such groups by one or several taxonomic characters. (Mayr, 1943, p. 136.)
>
> In summary, the criterion for subspecies is intergradation, that for species is lack of intergradation, and that for genera is degree of difference. (Hall, 1943, p. 142.)

According to the geographical species concept, as it is generally understood, there can be no gradation between individuals constituting the different larger groups or species. If gradation occurs only a single species can be recognized. The degree of difference between different subspecies depends upon the completeness of their isolation and the length of time that such isolation has existed. Subspecies that are most separated geographically generally differ most and, if groups of individuals in intermediate areas were ignored, differences between widely separated subspecies might cause taxonomists to consider them distinct species. Many species have been described and later reduced to the rank of subspecies when connecting forms were discovered.

> Subspecies borders are generally drawn where there is a distributional gap, or a change of environment, or a significant change in the taxonomic characters of the continuous populations. (Mayr, 1943, p. 137.)

The two principal factors in the biological differentiation of groups of individuals into species and subspecies are time and the fact that inheritable changes are continuously taking place in the germ cells of organisms. A new mutation appearing in one individual, ultimately may become a character of its group. The laws of chance make it improbable that the same mutation will appear commonly in another isolated but related group, and it is far less likely that the same combination of several new mutations will be duplicated.

Several difficulties are met in attempting to apply the subspecies concept to fossils. The biologist has to deal only with the present whereas the paleontologist is concerned with organisms as they lived and varied throughout considerable intervals of time. Faunas and floras in the geologic past, as at present, inhabited provinces and subprovinces. The degree of isolation of marine

organisms depended upon three factors, (1) size and position of land masses, (2) distribution of ocean currents and (3) general temperature conditions which reflected, in part at least, the first two factors. The possibility however, that temperatures were influenced in other unknown ways can not be ruled out entirely.

The writer proposes to refer to closely related fossil groups, similar to the subspecies recognized in modern faunas and floras, as paleo-subspecies. There is no way of distinguishing a geographical subspecies from a paleo-subspecies. The distinctive characters of each depends upon the length of time and the degree to which it has been separated from other related groups.

One of the difficulties encountered in the use of paleo-subspecies for correlation is the probability that contemporaneous paleo-subspecies differed as greatly among themselves as did groups of the same species that lived at slightly different times. If differences are noted between individuals of a species collected from successive stratigraphic zones within the same province or subprovince it is fairly probable that they are the result of evolutionary processes. This conclusion is almost certain if the indicated changes are progressive; in other ways, fossils present little or no evidence to indicate whether observed differences between closely related groups of less than specific rank resulted from contemporaneous geographic variation or from evolution during the passage of time.

It is a well known fact that no two zones, even in the same area, contain exactly the same highly ornamented species or assemblage of species unless they were separated by a very short period of time. More generalized types may occur in more widely separated zones but the longer the time interval, the greater the differences between the fossil assemblages. Species in adjacent zones, not separated by a marked hiatus, are more nearly alike than are those in zones which are stratigraphically farther apart. Even though two related groups in adjacent zones may be composed mainly of distinctive individuals each group may contain some that cannot be distinguished from individuals in other zones. Here is the same problem that meets modern taxonomists except that time is substituted for distance.

If it were possible to study a continuous fossil record in a series of sediments deposited without interruption under similar physical conditions and in the same geographic province during a long period of geologic time, the progress of evolution could be accurately observed. Faunas at the top and bottom of this succession might be very different and the related forms in each might be considered distinct species.

A study of all intermediate faunas, however, would probably show a continuous gradation between these species and the changes appearing from zone to zone would be so slight that they could be indicated only by statistical methods.[1] Consequently the groups that appeared to be represented by two distinct species, would prove to be only the end members of gradational series which could not be broken into distinct species.

Such a hypothetical situation rarely, if ever, occurs but many stratigraphic sequences are known where similar assemblages of species are present in many different zones, indicating a repetition of similar ecological conditions. In such a sequence, the same species may recur in many different zones, but in each succeeding zone its representatives are likely to show variants different from those present in any other zone, although they are obviously related and intergrade. Comparatively little study has been devoted to such closely related faunas of the Cenozoic period, and this is a very important field for future research. Among both modern and fossil organisms the distinctness of such groups depends primarily upon the length of time that they have been separated. Neozoologists recognize that there is a practical limit to the boundaries used in separating subspecific groups, but there is no general agreement as to what percentage of variants should be distinctive before a group should be recognized as a subspecies. In discussing the problem of dividing lines between subspecies Mayr (1943, p. 137) states

> A detailed analysis of the populations near subspecies borders show in many cases that the change from one subspecies into the next is so gradual that the placing of these borders is left

[1] These small differences would be paleo-clines equivalent to the clines of Huxley.

to an arbitrary decision. In other cases equally arbitrary decisions must be made concerning the degree of difference between two groups of populations which is to be considered sufficient for separation of subspecies. There are splitters and lumpers. In general it is stated, in the ornithological literature, that 75 per cent of the individuals of one race must be clearly separable from all the individuals of the other race. This is a very unsatisfactory method of handling the problem, since the status of many subspecies changes with the increase in number of collected specimens. A way should be found to express the necessary degree of distinctness in more absolute terms, such as standard deviations. Beginnings are being made along these lines, but they have not yet found their way into the taxonomy of birds.

Paleontologists in general have been loath to recognize subspecies because all possible intergrading forms, such as the taxonomist of modern faunas or floras would demand, are very rarely available for study. Many fossil specific lineages are known which have a fairly long geologic range. These may be referred to as evolutionary species, the equivalent of the super species of Mayr (1942, p. 169), each being derived from the one that went before and ancestral to the one that follows. In a large proportion of such cases there are no known gradations between these species. This situation undoubtedly is more apparent than real and the intergrading forms that probably existed have not yet been found. There are, however, examples of species which do intergrade. Two species, as originally known and defined, may not have shown any gradations, but specimens from a new locality may be found that are intermediate and connect them. Such a new locality will probably represent an intermediate zone filling in the time gap between the two original species. In such a circumstance the tendency has been to continue to recognize two distinct species and to consider that they are associated at the new locality even though the evidence shows the forms to intergrade. Similarly early collections of modern faunas and floras lacked gradations between described species but later these were discovered in intermediate localities and the original species were reduced to subspecies. A similar course should be followed in the taxonomic treatment of intergrading fossil species.

Because the element of time is unimportant to the modern biologist the situations with regard to living and fossil species are somewhat different. Closely related modern species which are not connected by gradations generally are restricted to different geographic areas separated by distinct barriers across which the species cannot migrate. Under such conditions intergrading forms may no longer exist to connect the groups especially if the barrier has persisted for a considerable time. With the fossils, however, forms connecting two such species may be expected to turn up in collections obtained from intermediate zones.

In a way, the study and classification of modern organisms may be considered as enclosed in a frame of two dimensions, the figurative length and breadth of the modern world; but the paleontologist is also concerned with a third dimension, time.

Because the paleontological record is so incomplete many fossil species appear to be distinct entities. Experience has shown, however, that the more complete the record the more difficult it is to make separations and, as with Recent faunas and floras, the paleontologist with new data is forced to divide his species into smaller closely related groups or paleo-subspecies.

Because of the subjective element in taxonomy the paleontologist finds himself in a quandary when it comes to evaluating the importance of different groups as recognized by different taxonomists. In some groups, for example the ammonites, many of the recognized genera appear to be equivalent in rank to the species of other molluscan groups and their species probably correspond in importance to subspecies or even varieties in the other groups. Thus the value for correlation of apparently corresponding taxonomic groups may vary considerably and an ammonite genus may prove as effective for precise correlation as a gastropod or pelecypod species.

IS SPECIATION ENTIRELY THE RESULT OF ADAPTATION?

The idea that new mutations in a species are the result of changes in the germ cell rather than of the direct influence of environment has an important bearing on the species problem. Paleontological literature is

full of references to the importance of the direct influence of environmental factors in the production of species and many paleontologists and other biologists have maintained, as some still do, that all specific as well as generic changes are adaptive.

The concept of the constant appearance of new mutations independent of environmental conditions is not a new one. Darwin entertained it, together with the idea that the direct influence of environment was a factor. He was a Neolamarkian and even today a considerable number of paleontologists and other biologists lean in that direction. Experimental biology and genetics, however, do not bear out this point of view. The modern concept is that adaptation is possible because changes are continually taking place in the genes of organisms and that those mutations which are beneficial to the organisms survive whereas those that are detrimental do not.

The question naturally arises is every new mutation either harmful or beneficial to the organisms? To the writer it seems most probable that a large proportion of them are neutral, and, therefore they would be inherited according to the Mendelian law. The accumulation of some neutral characters and the disappearance of others might produce marked changes in the superficial characters of a species without any evidence of new adaptive changes, and the altered group might continue to live in the same environmental niche as did its predecessors. According to this concept, species are probably changing constantly irrespective of their environment. Adaptation and speciation may be two fundamentally similar but distinct processes.

Mutation, somewhat like radiation in radioactive minerals, is constantly occurring. Adaptation, however, is a discontinuous process which takes place most rapidly at times or places of environmental change, when or where new niches and therefore new or different opportunities are open to the organism. But are not species constantly changing even when new adaptations are not necessary?

Many modern geneticists believe that subspecific changes occur largely as the result of adaptation. Huxley (1940, p. 2) in discussing this problem states:

> There is still a widespread reluctance, especially among the younger experimental biologists, to recognize the prevalence of adaptation and the power of selection. This is, doubtless, in large part a natural reaction against the facile armchair reasoning of certain schools of earlier evolutionists.
>
> One of the most striking features of recent evolutionary theory has been the swing back to a selectionist interpretation after the antiselectionist interlude initiated by Bateman, De Vrees and Morgan. It should be further emphasized that this has been most marked among those who have been in closest genetic contact with the problem—men like Muller, Sturtevant, Timofeeff, Rossovsky and Ford as well as among the mathematical group of deductive selectionists. We may safely prophesy that the antiselectionist's views of those not so directly concerned with the machinery of evolution, notably among the experimental biologists and paleontologists will be dissipated as the implications of modern genetics become more widely realized.

It is doubtful that a majority of geneticists agree with Huxley's statement. Wright (1940, p. 179), a well known investigator, in discussing this problem presents a very different point of view.

> Attempts to make evaluations of the roles of an adaptive and random differentiation have led to the most diverse conclusions because of the lack of objective criteria. The publication of Darwin's Origin of Species was followed by intensive and ingenious attempts to interpret all sorts of species-differences as adaptive under the belief that natural selection was the sole controlling principle of evolution. (Wallace). In recent years Fisher has maintained on theoretical grounds that evolution of organisms is as completely subject to the net selection-pressures on the separate genes as the history of physical systems is subject to the increase of entropy. From the viewpoint of the present paper, however, this does not appear to be a necessary theoretical conclusion. Even from the first, certain authors (e.g. Gulick and Romanes) maintained that it was futile to look for a selective mechanism back of many of the differences between isolated populations living under substantially identical conditions. The majority of systematists have probably been sceptical of the adaptive significance of all taxonomic differences.

As pointed out by Huxley, acceptance of the concept that subspecies result from adaptation involves the conclusion that the rate of evolution should be different in different parts of the world. Thus, as he suggests, evolution of species might be more rapid in tropical than in boreal and austral regions because in such areas the reproduction process would be most rapid. In the

writer's opinion the paleontological record furnishes little, if any, evidence that such has been the case. There can be very little doubt that adaptation has often been an important factor in the production of subspecies and species but the assumption that all such changes have been brought about by that process is most questionable.

If all speciation resulted from adaptation any group well adapted to a constant environment would remain appreciably unchanged while the same group or a portion of it living at the same time in another area of changing environment would evolve. Thus the evolution of species would occur at different rates in different provinces. Under such conditions it would not be possible to apply the Lyellian percentage method for long distance correlations.

T. Wayland Vaughan (1924, p. 685) in discussing the percentage method and its defects stated:

> The Lyellian method is based on two assumptions, one of which is that standard of discrimination of species of mollusks of Deshayes will be that standard of other workers, and the other is that the rate of organic changes is the same in all parts of the world. Both of these assumptions seem to be erroneous . . .
>
> Unanimity of treatment of the species of the different groups of organisms has not been obtained, and it may be rather confidently predicted that it never will be . . .
>
> Discrimination between species, so called, is now much finer than in the days of Lyell and Deshayes, and now about the same percentage of recent species is recognized in deposits of older Miocene age (Langhian) that Lyell considered characteristic of the Eocene . . .

Vaughan further stated that a considerable number of species found in Tertiary strata of the Atlantic region are represented by closely related congeneric species now living in the Pacific. None of the species are identical but the genera have a long geologic range. He quotes Prof. K. Martin, who stated that the Miocene faunas of the East Indies have a much larger percentage of living species than do the corresponding faunas in Europe but later workers are not so certain of Martin's correlations. Vaughan also quotes P. Marshall regarding the faunas of New Zealand: "It is probable that a fauna in New Zealand with 20 per cent of Recent species would have a much greater antiquity than a fauna with a similar percentage of Recent species in Europe or America." Here, however, there is very little on which to base correlations with Europe because the faunas have practically nothing in common. As far as the writer is aware no European Miocene species has been certainly recognized in the faunas of New Zealand.

There are many molluscan genera that are common to the tropics all over the world and this is also true for the faunas of the temperate, boreal and arctic zones. Many of these genera also occur in the oldest Cenozoic deposits; a smaller, but still a considerable number, are present in Mesozoic deposits and a few modern genera extend back to early Paleozoic time. There are, however, no molluscan species with such extended geologic ranges.

Species generally have short geologic ranges and every major stratigraphic zone from the Pleistocene to the base of the Paleozoic has its distinctive species. Species have been constantly changing but many genera have retained their characters for long periods of time. Very few molluscan species (excepting generalized ones lacking characters useful for discrimination) range from the Paleocene to the Upper Eocene and the deposits of these ages in western North America can be divided into at least six major faunal zones. Changes in the molluscan species (they are members of tropical faunas) occur at a more or less constant rate from the lowest to the uppermost of these zones and the individuals from adjacent stratigraphic zones have, of course, more in common than those of less closely associated zones. All these faunules are related and the assemblages are very similar but each zone has its distinctive species and subspecies. Only a few generalized forms are common to the different zones. A large proportion of the species in the lower zones are ancestral to those in the upper ones. Many of these specific strains continue into the Oligocene and some persist into the Miocene. Similar relations occur in the known Eocene faunas of the southern United States and South America.

The species in these faunules that have the shortest ranges are the ornamented forms and many of them intergrade just as living subspecies in adjacent subprovinces

intergrade. The best examples occur among the gastropods. Merriam (1941, pp. 42–44) recognized 10 subspecies of *Turritella uvasana* from the Eocene of the West Coast and pointed out that there are several other species in the Oligocene and one in the Miocene that belong to this same lineage. Wherever fossil faunas have been studied in detail such long-ranged lineages have been recognized. Numerous examples of evolutionary species[2] have been described; some of the best of these occur among the Ammonites. The progressive changes in these lineages are so constant that in going from one stratigraphic zone to another the amount of change can be predicted fairly accurately according to the interval of time involved. In spite of these changes there is little, or no evidence of any appreciable progressive change in environment from one zone to another.

These observations suggest that such generic changes as took place were at least in part the result of adaptation but that as long as an environment remained more or less the same, generic development was static while species changed continually because of the constant appearance of new mutations many of which were neutral so far as their adaptive value was concerned.

The idea that changes in species can and have occurred as the result of the accumulation of new characters furnished by neutral mutations does not preclude the importance of changing environment and adaptation as a cause of specific change. Generic changes, because of their more fundamental nature, are generally conceded to be results of the adaptive process but generic change necessarily involves specific changes that are the stages in the development of a new genus.

If the above concepts concerning the origin of fossil subspecies are true, it is probable that a large proportion of modern geographical subspecies developed in the same manner, as the result of isolation rather than environmental change and adaptation. As a rule the species which constitute a single lineage (some lineages persisted from Mesozoic to Recent) all lived under similar environmental conditions. A lineage adapted to tropical waters almost invariably remained in such an environment while new specific characters appeared. The association of genera in early Cenozoic boreal faunules of northern Europe is fairly similar to living associations. The same is true for later Cenozoic faunules of boreal, temperate and tropical types.

It would seem reasonable to believe that such generic changes as took place were in large part the result of adaptation. Genera were long-ranging because they were well adjusted to their environments and there was little cause for change. Species, however, changed constantly because of the continuous appearance of new mutations of neutral value so far as habitat was concerned. The appearance and continuation of some mutations and the disappearance of others has resulted in the gradual transformation of genera, a process in which adaptation was necessarily involved, and while such generic changes were taking place, new species and subspecies might make their appearance as the result of adaptation, provided the changes were gradual.

Molluscan species are generally of limited usefulness for correlations between widely separated provinces because of the isolation of faunas and the fact that a large proportion of the species are confined to shallow waters. There are, however, some eurybathal or eurythermal modern species which have wide geographic ranges and some stenothermal, shallow water types are distributed by ocean currents, either when attached to foreign objects such as seaweed, or drift wood, or with the plankton during their larval stages. Such types undoubtedly existed in past times, and should be of value in correlation. Also there have been times when climatic conditions were more uniform and species had much wider geographic ranges than at present and under such conditions correlations are more easily established.

The writer cannot agree with Davies' (1934, p. 52) statement that "mollusca in general are too long-lived as species and too stenotopic to be of much time value." General experience has shown that within a

[2] An evolutionary species may be defined as a series of successive species or subspecies each one having been derived from the one preceding it and ancestral to the one following.

province, species correlations are dependable and that many species had fairly wide geographic ranges and give evidence for correlations between major provinces. There is good reason to believe that future work will reveal more such species.

Because of advances in the biological sciences, the modern concept of a species is very different from what it was in the past. Smaller differences are now noted and these are known to be genetic and inherited in the germ cell. Each species consists of a considerable number of mutations or variations which may be notably different in different habitats. Sufficient specimens have been collected to demonstrate that certain groups of variants either do or do not intergrade and on that basis the biologist sets up his species and subspecies. The tendency has been, and there is no escape from it, to split groups into finer and finer subdivisions. Invertebrate paleontologists have followed the biologists in this splitting and the species that is now usually recognized is very different from the species of a few years ago. Such splitting is generally warranted but most paleontologists are loth to recognize subspecies and are inclined to give specific names to these smaller groups. The question arises—Are not many of these fossil species comparable to living subspecies? The writer believes that many of them are, even if no intergrading forms are known. Many differences between fossil species distinguished by paleontologists are no greater than those separating modern subspecies. Although intergrading forms may be unknown they probably existed and may be found when more complete collections are studied.

This point of view has been criticized as being too subjective because it cannot be readily proved. All concepts as to the nature of a genus, a subgenus, or even a species are, however, more or less subjective.

Most Cenozoic correlations have been based upon individual judgments as to the probable relationships of species occurring in different provinces. Very few of the species now recognized in the Eocene of North America are identical with European species but many of them appear to be closely related. Finely discriminated species have proved valuable for correlations in individual major provinces but it seems to the writer that recognition of closely related groups as paleo-subspecies rather than species is more practical. By the recognition of paleo-subspecies evolutionary trends in the more inclusive species would be clearly indicated and it would be much easier for the paleontologist or geologist to evaluate the significance of groups of specimens that do not quite match described forms. If these specimens are obtained in the same province, they will probably be found to be intermediate forms characteristic of intermediate beds. If they come from different provinces or different continents their time significance is more readily apparant.

MIGRATION OF RECENT MOLLUSCAN SPECIES

Molluscan species used for Cenozoic correlations are principally shallow water forms, gastropods and pelecypods. The great majority of living marine species are limited to comparatively shallow water on the continental shelves and surrounding the oceanic islands and most of them are members of local faunas characteristic of many more or less distinct provinces. Data on the character and distribution of the major provinces has been well summarized (Davies, 1940, pp. 11–45).

There are a few species, however, that are more tolerant to temperature changes and some have ranges that extend from shallow to fairly deep water. Such exceptions, because of their wide distribution, should be important for correlation if they can be recognized among the fossils.

Most marine molluscs pass through a free swimming larval stage, during which migration may take place. This stage is of short duration, from a few days to two to three weeks at most. The larva of a stenothermal, warm water species which is not tolerant to low temperature may be carried into deep water by ocean currents but when the larval stage is passed and the maturing individual drops to the bottom, it will die. Such a species could be carried along the continental shelves and survive in a new locality where temperature conditions are suitable or it might be carried from one island to another if the passage could be accomplished during the span of the creature's larval stage. The duration of one free swimming larval stage, however, is not suffi-

cient to permit the migration of stenothermal tropical or subtropical shallow-water species across the Atlantic or Pacific by ocean currents at the present time. Nevertheless there is a considerable number of such species common to the two sides of these oceans. How did they get across?

The majority of marine molluscan assemblages of theArctic, Antarctic and boreal regions are very different both generically and specifically from assemblages in the temperate zones. The latter faunas, in turn, are very different from those of tropical waters. Some species living in shallow northern waters have been dredged from deep waters farther south and a few have been found in deep tropical waters. Very few shallow water species are common to the Arctic or boreal and temperate zones or to the temperate and tropical zones. Most molluscan genera and species in all zones are stenothermal.

Differentiation of modern generic assemblages according to temperature appears to have resulted from adaptation, which must have been operative at least as far back as the Paleocene and probably much farther. There is no evidence that any important shifting of genera from one temperature assemblage to another has occurred during the Cenozoic era. Faunal assemblages shifted at various times with shifting of the isotherms and undoubtedly were much influenced by changes in positions of the ocean currents. At various times during the Cenozoic era the boundary between northern and southern faunas shifted either to the north and south of its present position. For example a boreal fauna invaded northern Europe from the north during the Paleocene. During the Eocene, a tropical or subtropical fauna reached the same area from the south. During middle and upper Eocene times tropical molluscan faunas lived on the west coast of North America as far north as western Washington where temperate faunas now occur.

Such northward and southward migrations along the continental coasts are readily understood. The possibility of migrations from the coast of one continent to another, however, is an entirely different problem.

A number of species that are circumboreal in their distribution are common to the northern coasts of Eurasia and North America and a few of these range into temperate waters also. There are very few shallow-water Arctic or boreal molluscan species in the tropics, however, and those which do occur exist only in the deeper colder water.

There are at present no shallow water connections across the tropical Atlantic or Pacific Oceans. Most of the shallow water tropical species are different on the opposite sides of these oceans, but there are some exceptions. There are many more species common to the east and west sides of the tropical Atlantic than there are to the tropical waters of the east Atlantic (including the Mediterranean) and those east of the Suez Canal, i.e. the Red Sea and the Indian Ocean. According to Davies (1934, p. 19) about 50 species of mollusca are common to the west African and the Caribbean province and very few of these extend into boreal or austral waters. Maury (1919, 1921) lists 34 species common to the Gulf of Mexico and the coasts of Europe and Africa, including the Mediterranean. Most of the Gulf of Mexico fauna is common to the Caribbean and the east coast of Brazil. It consists mainly of tropical shallow water species unknown in northern waters but 14 have been identified on the shores of northern Europe and England, two have been reported from Arctic waters and several others occur on the southeast coast of Africa. Probably most of the species found also in northern waters migrated along the shallow coasts but some may have been so tolerant to temperature that they were able to migrate directly across the bottom of the ocean. Maury lists three Gulf of Mexico species from the southeast coast of Africa and two from the Indian Ocean. Out of more than a thousand known tropical species on each side of the Atlantic less than one hundred (a liberal estimate) are common to both sides.

A few tropical species are common to the two sides of the Pacific Ocean. Hertlein (1937, pp. 310–312) lists 28, most of which are stenothermal. This is a very small part of several thousand species that are recognized.

A somewhat larger proportion of species is common in the boreal and temperate

waters on opposite sides of the Atlantic and Pacific oceans but as a whole the faunas are very different. Myra Keen (1941, pp. 479–483) lists 36 gastropods reported on both the Japanese and California coasts, of which 21 are confirmed, and 66 species of pelecypods of which 28 are positively and 43 partially confirmed.

These figures clearly show the great differences between the faunas on opposite sides of the two major ocean basins and it is logical to conclude that these differences are the result of isolation and the inability of most species to cross deep waters.

Land barriers are equally important in the separation and differentiation in faunas. The two greatest continental barriers between the oceans were formerly pierced by portals at the Isthmus of Suez and the Isthmus of Panama.

According to Davies (1934, p. 18) only 8 molluscan species are common to the Red Sea and the Mediterranean. They are all widely distributed forms and occur on both coasts of Africa.

The fauna of the Caribbean and that of the Panama province of the Pacific have a much larger percentage of common species. This closer relationship is generally recognized to be the result of the more recent separation of these provinces which dates from about the beginning of the Pliocene period, whereas the Red Sea and the Mediterranean have been separated since some time in the Eocene. None of the Eocene species that formerly inhabited the eastern provinces is now living but the species common to the two sides of Panama have survived from the Pliocene period or are sufficiently tolerant to temperature changes to permit them to migrate around the coast of South America.

The question remains, however—how did the shallow water tropical species common to the opposite sides of the great oceans and which do not occur in northern or southern waters migrate across the Atlantic and the Pacific? It is very improbable that they achieved this passage during their free swimming larval stages and the writer is inclined to believe that they were rafted across.

In the adult stage some molluscs are attached to floating objects such as driftwood, or seaweed and others, like *Teredo*, bore into wood. Such forms could have been carried across the ocean. Tropical species of this type would probably travel from east to west as that is the direction of the present warm water currents in both the Pacific and Atlantic.

At present there are numerous molluscan provinces, both major and minor, bordering all the land areas of the world. In general there is a gradation between the species of adjacent provinces bordering each continent and temperature has been the most important factor in the differentiation of these assemblages. Many Arctic species extend into boreal waters, some boreal species occur in temperate waters and some temperate species persist into the tropics. A few Arctic and boreal species occur in tropical areas but generally the southward range of northern species carries them into deeper and deeper waters because they are tolerant to depth but not to temperature. Most faunas of the temperature zones are very distinct, each having not only its peculiar species but its peculiar genera as well. These distinct assemblages appear to be adaptations to temperature which took place early in the Cenozoic era, if not earlier.

Faunas of adjacent major provinces of each of the continental borders have more species in common with each other than with provinces in the same latitude on other continents. Faunas of the Arctic and boreal provinces of different continents have more in common than do those of the temperate or tropical provinces. Arctic faunas, and also some species of the boreal provinces, have been able to migrate along the shallow waters north of Eurasia and North America for in the north there are no wide stretches of deep water. Temperate and tropical faunas, however, are separated by wide deep water barriers.

These circumstances suggest that if conditions in the Cenozoic era were similar to those existing today, correlation could be most easily established by the identity of species method in the different Arctic and boreal provinces but there should be some species common to the various temperate and tropical provinces. But were conditions during the Cenozoic era the same or very different from what they are today? So far

as the writer is aware, most invertebrate paleontologists concede that conditions during the Oligocene, Miocene, Pliocene and Pleistocene periods were very similar to those now existing but it is possible that during the Paleocene and Eocene periods they were quite different.

R. Rutsch of the University of Basel has concluded that the Paleocene and Eocene marine invertebrate faunas of Europe and North Africa are so similar to those of South America and the Caribbean islands that there must have been an easier migratory route then than in later Cenozoic time or at the present. He suggests that the continents on the two sides of the Atlantic might have stood closer together or that there may have been a series of closely spaced islands that permitted the migration of shallow water mollusca during their free swimming stages. His conclusions are as follows (Rutsch, 1940, p. 625):

> The benthonic mollusks of the tropical American Paleocene, and probably also of the Eocene, show close connections with those of North Africa. This relationship is so close that the existence of an Atlantic Ocean in its present form is almost precluded, as far as the oldest Tertiary is concerned.
>
> Already during the Oligocene, and especially during the Miocene period, the differentiation is more clearly defined, the faunas being much more similar to the present faunas of America.
>
> A separation into zoogeographic provinces similar to those of the living benthonic mollusks of the east and west coasts of the Atlantic was probably in existence during the Tertiary, although in a dissimilar form. This is of the greatest importance for a comparative biogeographic research of Tertiary shallow-water mollusks on both sides of the Atlantic.
>
> The close connections between the oldest tropical American and South European-North African Tertiary faunas can be explained by several theories, of which the continental drift theory of Alfred Wegener is certainly the most probable.

The writer, however, does not agree with Rutsch as his studies of the Eocene and Paleocene faunas of North and South America and the Caribbean islands have led him to entirely different conclusions.

The writer is particularly impressed by the small number of Paleocene or Eocene species in the Western Hemisphere that are identical with European or African species. The species described from these faunas come from numerous distinct zones. In the faunas of North America there are numerous evolutionary series which are almost all considered to be distinct species. Many of the species in large collections intergrade between the different zones but because the minor differences have not been recognized they are considered to have long stratigraphic ranges. Although two specific names have been given to different members of some of these evolutionary series, no varietal or subspecific names have been applied to them. Each is represented by well defined paleo-subspecies in several successive horizons to which too little attention has been paid.

Correlations between Paleocene and Eocene strata of the western and eastern hemispheres have been based mostly upon analogous species, that is, species which are similar but are not known to grade into one another. It is possible, however, that many intergrading forms may be found by future study.

Rutsch (1939, pp. 621–624) lists one species of *Venericardia* as common to the Paleocene of Europe and the Midway of the eastern United States. He lists a gastropod, *Clinuropsis diderrichi* Vincent, as occurring in the Soledad Rock (Paleocene) of the Caribbean and the Paleocene of the Belgian Congo. The presence of the pelecypod genus *Raetomya* in the Eocene of Peru and Africa is cited as another example of the similarity of faunas. A species of gastropod genus *Tubulostium* likewise is common to the Upper Eocene of Texas and Europe.

Venericardia planicosta from the Paleocene of the eastern United States is considered by Gardner and Bowles (1937) to be different from the species in the Paleocene of Europe. In the writer's opinion, however, these two forms are similar enough to be regarded as paleo-subspecies of the same species.

The writer does not wish to belittle the value of the species used by Rutsch in his correlations but it is a fact that they are very few. They are fewer than the species common to the two sides of the tropical Atlantic at the present time. This evidence certainly does not favor Rutsch's hypothesis and it is highly probable that if there had been close connections between the tropical seas of the eastern and western hemispheres in

the early Tertiary a much larger proportion of common species would be recognized.

Clark and Vokes (1936, pls. 1 and 2) figured 18 species from West Coast Eocene deposits (mostly from the Middle Eocene) that are so similar to European species (mostly of the Middle Eocene) that they were considered to be analogous species. Later studies have shown that there are several other similar forms. A large proportion of these similar species show no greater differences than those which differentiate well established modern subspecies.

Clark and Vokes concluded that the presence of these species on the West Coast indicated direct migration between two major provinces during Eocene time. The tropical character of the Eocene faunas would make it improbable that migration occurred by way of the Arctic or around the south end of South America, therefore, it must have occurred when the Pacific and Caribbean sea were connected. Because of the east to west direction of the main ocean currents in the tropical Atlantic, migration must have been in that direction. The comparatively small number of such similar species suggests that they did not migrate along shallow-water connections, but were carried across the Atlantic as plankton, either by means of rafting or during the free swimming larval stage of their development although it is questionable whether the larval stages were of sufficient duration to have permitted their transit across the ocean.

Evidence that seems to be significant in the application of this hypothesis as the means of migration in the Eocene faunas concerned may be summarized: (1) The relationship between the California and the European Eocene faunas is expressed in the presence of a small number of closely related forms, in faunas containing a large number of forms that are wholly dissimilar. The related forms may be explained[3] as being those species which possessed a mero-planktonic larval period of sufficient length to permit their transportation across the ocean basin; the non-related species being those which either did not have a mero-planktonic larva, or whose free-swimming period was too short to permit trans-oceanic migration. (2) In the California Eocene deposits, the species that are closely related to the Paris Basin species are all of genera that are present throughout the middle Eocene deposits of Asia and Africa, as well as in North America. (Clark and Vokes, 1936, p. 871.)

[3] The writer would now say partially explained.

SUMMARY AND CONCLUSIONS

This paper's main thesis is that the most important means of correlating marine Cenozoic deposits is the species method. Emphasis is placed upon the importance of the geographical, distributional and genetic studies which have revolutionized former concepts of the species. Modern concepts of geographical species and subspecies may be applied equally well to fossil species, although many difficulties arise that are not encountered in the study of living organisms. Some of these difficulties are (1) The imperfection of the fossil record; (2) the many changes occurring in species during the passage of time; (3) the fact that paleo-subspecies, especially those of different provinces, may be contemporaneous rather than of different time significance.

Geographical and paleo-subspecies cannot be distinguished; both result from variation during the course of time. Geographical subspecies have been produced, for the most part, by isolation, and the differences between them depend upon the degree and duration of that isolation. Paleo-subspecies (or stratigraphic subspecies) also resulted from variation during the course of time, but with them no physical barriers were necessary because time itself separated the faunules. In both types of subspecies changes were produced by the constant appearance of new mutations some of which contributed new characters to the race while others were eliminated. The paleontological record shows conclusively that no invertebrate marine species or subspecies remained static for any considerable length of time and ornamented types give evidence of the most rapid changes. Many genera, however, had long geologic ranges.

Many biologists believe that all specific changes are the result of adaptation. The writer does not doubt the importance of adaptation in the evolution of some species or subspecies but the paleontological record shows that numerous specific and subspecific changes occurred where there was no apparent comparable change in environmental factors. So far as can be determined, a large proportion of the different lineages of molluscan species, lived throughout their entire stratigraphic range under similar environmental conditions.

There is no evidence that the evolution of species has been more or less rapid in any temperature zone.

It is assumed that each subspecies lived contemporaneously or nearly so wherever it existed. Correlation by the identity of species requires the recognition of contemporaneous forms in the strata of different provinces.

Living molluscan faunas of the corresponding provinces, especially in the tropical zone, on opposite sides of the oceans, are very different. Each has been so well isolated from the other that comparatively few species or subspecies are known to be common to both sides. Long-ranging species, however, may occur in several widely separated provinces. Detailed Cenozoic correlations are difficult to establish because of the great differentiation of faunas in different provinces. Future detailed studies will probably reveal a larger and larger number of species or subspecies common to different provinces which will provide the basis for more accurate correlations.

At many times in the geologic past climatic conditions were more uniform than they are at present. During such times species and subspecies had much wider geographic ranges and their fossils make widespread correlations possible. Conditions appear, however, to have been less uniform in the Cenozoic than in the Paleozoic and Mesozoic eras.

The writer does not agree with Davies (1934, p. 52) that "Mollusca in general are too long-lived as species and too stenotopic to be of much time value." They furnish excellent means for correlations within the major provinces.

This paper has been confined to a discussion of the molluscs and their application to correlation by the identity of species method. Other groups of marine invertebrates, particularly the Foraminifera and the Radiolaria, however, are probably more important for this purpose.

A very large proportion of the Foraminifera are benthic, a lesser number are pelagic. Many of the benthic type are found in fairly deep water where the temperature is low and uniform throughout large areas. Some of these species are cosmopolitan and common to all of the temperature zones. Some of the pelagic species are equally widespread.

The importance of foraminifera for correlation purposes has only been recognized comparatively recently. Every major zone of the Cretaceous and Cenozoic is now known to have distinctive species and in the major provinces at least these can be used to establish exact correlations. Some of these species occur in more than one major province and future work will probably bring to light other species of great usefulness. As these studies are continued the Foraminifera will probably be found more useful than the Mollusca for detailed correlations.

The Radiolaria also offer many possibilities. The numerous species are all pelagic. Many of them are cosmopolitan and occur in all the oceans. Studies by the writer and A. S. Campbell on upper Cretaceous Eocene, and Miocene Radiolaria from California,[4] (in part unpublished) have found no species common to the beds of these different ages. Also, no modern species were recognized in these faunas. All evidence suggests that specific changes were rapid in the Radiolaria. Most of the tests are more complicated and more highly ornamented than the Foraminifera. As study of this group continues its value for detailed correlations between widely separated provinces will probably be established.

REFERENCES

CAMPBELL, ARTHUR S. and CLARK, BRUCE L., 1944, Miocene radiolarian faunas from southern California: Geol. Soc. America Spec. Papers 51, pp. 1–76, 7 pls.

CLARK, BRUCE L. and VOKES, HAROLD, 1936, Summary of marine Eocene sequence of western North America: Geol. Soc. America Bull., vol. 47, pp. 851–878, 2 pls., 3 figs.

CLARK, BRUCE L. and CAMPBELL, ARTHUR S., 1942, Eocene radiolarian faunas from Mount Diablo area, California: Geol. Soc. America Spec. Paper 39, pp. 1–117, 10 pls.

DAVIES, A. M., 1934, Tertiary faunas, vol. 2, Thomas Murby and Co., London, pp. 1–252.

DOBZHANSKY, THEODOSUS, 1941, Genetics and origin of species, Columbia University Press.

GARDNER, JULIA and BOWLES, EGAR, 1937, *Venericardia planicosta* group in the Gulf Province: U. S. Geol. Survey Prof. Paper 189, pp. 143–215, pls. 29–46, fig. 27.

[4] Clark and Campbell, 1942; Campbell and Clark, 1944.

HALL, E. RAYMOND, 1943, Criteria for vertebrate subspecies, species and genera; the mammals: New York Acad. of Sci. Annals, vol. 44, art. 2, pp. 141–144.

HERTLEIN, L. J., 1937, A note on some species of marine Mollusca, occurring in both Polynesia and western America: Am. Phil. Soc. Proc., vol. 78, no. 2, pp. 310–312.

HUXLEY, J. S., 1940, Towards the new systematics, Oxford Clarendon Press, pp. 1–46.

KEEN, A. MYRA, 1941, Molluscan species common to western North America and Japan: Sixth Pacific Sci. Cong., vol. 3, pp. 479–485.

MAYR, ERNST, 1941, Criteria of subspecies, species and genera in Ornithology: New York Acad. of Sci. Annals, vol. 44, pp. 133–139.

——, 1942, Systematics and origin of species, Columbia University Press.

MAURY, COLLETTE J., 1919, 1921, Recent Mollusca of the Gulf of Mexico and Pliocene; Pleistocene species from the Gulf States: Bull. Am. Paleontology, vol. 8, pt. 1, pp. 3–115, idem., vol. 9, pt. 2, pp. 34–142.

MERRIAM, C. W., 1941, Fossil Turritellas from the Pacific Coast of North America: California Univ. Pub., Dept. Geol. Sci. Bull., vol. 26, no. 1, pp. 1–214, 11 pls.

RUTSCH, R., 1940, Evolution of tropical American Tertiary faunas and theory of continental drift: Political Sci. Assoc. 6th Sci. Congress Proc., vol. 2, pp. 619–628.

SIMPSON, GEORGE G., 1943, Criteria for genera, species and subspecies in zoology and paleozoology: New York Acad. of Sci. Annals, vol. 44, art. 2, pp. 105–188.

VAUGHAN, T. WAYLAND, 1924, Criteria and status of correlation and classification of tertiary deposits; Geol. Soc. America Bull., vol. 35, pp. 677–742.

WRIGHT, SEWALL, 1941, Consequences of Mendelian heredity in relation to speciation: *In* New systematics, Oxford Clarendon Press, 1940, pp. 161–183.

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PALEONTOLOGICAL NOTE

GOLDIUS VERSUS SCUTELLUM

A. K. MILLER AND A. G. UNKLESBAY

Professor Curt Teichert has recently called our attention to the fact that in 1925 R. and E. Richter (*Senckenbergiana*, Bd. 7, pp. 239–241) showed that the valid generic name for certain of the trilobites we discussed on pages 363–365 of volume 18 of this Journal is *Scutellum* Pusch, 1833, rather than *Goldius* de Koninck, 1841.

REVIEWS

REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY No. 3—Harry S. Ladd, Chairman, National Research Council. 32 pages, mimeographed, 1943. $.50.

This report, presented May 1, 1943, contains announcements of investigations, recently completed or in progress, and recent publications. Several are more or less briefly abstracted including "Boring Sponges" by Marcus C. Old, "Certain Recent Geological and Biological Changes in South Texas, with Consideration of Probable Causes" by W. Armstrong Price and Gordon Gunter, "Biology of the California Sea-Mussel (*Mytilus californicus*); I. Influence of Temperature, Food Supply, Sex and Age on the Rate of Growth; II. Nutrition, Metabolism, Growth and Calcium Deposition" by Dennis L. Fox and Wesley R. Coe, "Ecology of Sand Beaches at Beaufort, N. C." by A. S. Pearse, "Great Barrier Reef Bores, 1926 and 1927, Descriptions, Analysis, and Interpretations" by H. C. Richards and Dorothy Hill, and "The Causes of the Vertical and Horizontal Distribution of Organism Between Tidemarks in South Africa" by T. A. Stephenson. Also included are three short papers, "Diatoms as Food of Oysters" by Thurlow C. Nelson, "Ecologic Relationships of Larger Foraminifera" by Earl H. Myers, and "Tertiary and Cretaceous Paleontology of California Based on Fossil Fish Remains" by Lore R. David.

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